STUDIES ON PHOSPHORUS NUTRITION OF TRITICALE

ABSTRACT

THESIS
SUBMITTED FOR THE DEGREE OF
Doctor of Philosophy
IN
BOTANY

NASREEN FATIMA

LABORATORY OF PLANT PHYSIOLOGY
DEPARTMENT OF BOTANY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

1993

ABSTRACT

Three field trials were conducted at Aligarh, Western Uttar Pradesh (India) during the winter season of 1989-91. Experiment 1 was a factorial randomised varietal trial on four newly released cultivars of triticale (Delfin, Driera, TL-419 and Tigre'S') and a wheat check (HD-2204). Out of the two basal phosphorus doses tested 60 kg P_2O_5/ha (P_{60}) proved superior to 45 kg P_2O_5/ha (P_{45}) for growth, leaf -N, -P and -K, leaf NRA, at three stages yield and quality characteristics, particularly in treatments where 50 kg N/ha was added by top-dressing at tillering stage to the plants grown with a uniform basal dose of 100 kg N and 30 kg K/ha. Delfin proved the best cultivar and the $N_{100+50}P_{60}K_{30}$ x Delfin, the best combination for commercial cultivation.

In Experiment 2 again a factorial randomised trial, supplemental spray of 4 kg P/ha applied as aquoues mono-calcium superphosphate to plants grown with basal $N_{100+50}P_{45}K_{30}$ (containing the sub-optimal phosphorus dose) in two equal splits at heading and milky grain stages (HM) proved more efficacious than spray of the same quantity of phosphorus either at tillering (T), heading (H), or milky grain (M) stages alone or at TH, TM or even THM, on the basis of yield and quality. The cultivar of triticale selected for this trial (Delfin) proved much superior to the wheat check on all

counts and HM x Delfin, the best combination, indicating the feasibility of economy of phosphatic fertiliser without sacrificing yield and quality.

In the last simple randomised trial (Experiment 3), undertaken to test the comparative response to three sources of phosphorus (monocalcium superphosphate, diammonium phosphate and sodium dihydrogen orthophosphate) applied HM to Delfin grown with $N_{100+50}P_{45}K_{30}$, monocalcium superphosphate was confirmed to be most efficacious on the basis of yield and quality characteristics. Being the least expensive source of phosphorus, it commends itself for adoption on commercial scale.

Large scale statistically designed visual and sensory tests showed that although triticale cv. Delfin was slightly poorer than HD-2204, the wheat check e.g. by 5% in flour extraction and with regard to quality of bun and chapatti the 1:1 blend of Delfin and wheat flour was acceptable on the basis of colour, shape and taste of bun and chapatti.

STUDIES ON PHOSPHORUS NUTRITION OF TRITICALE

THESIS
SUBMITTED FOR THE DEGREE OF
Doctor of Philosophy
IN
BOTANY

NASREEN FATIMA

LABORATORY OF PLANT PHYSIOLOGY
DEPARTMENT OF BOTANY
ALIGARH MUSLIM UNIVERSITY
ALIGARH (INDIA)

1993

DEPARTMENT OF BOTANY
ALIGARH MUSLIM UNIVERSITY
A L I G A R H—202 002
Telephone : 25676

Dated 28-12-1993

ARIF INAM
M.Phil, Ph.D.
Reader

CERTIFICATE

This is to certify that the thesis entitled **"STUDIES ON PHOSPHORUS NUTRITION OF TRITICALE"** submitted in partial fulfilment of the requirements for the degree of DOCTOR OF PHILOSOPHY in BOTANY is a faithful record of the bonafide research work carried out at the ALIGARH MUSLIM UNIVERSITY, ALIGARH by **Mrs. NASREEN FATIMA** under my guidance and supervision and that no part of it has been submitted for any other degree or diploma.

(ARIF INAM)
Supervisor of Research

ACKNOWLEDGEMENTS

I am grateful to **Dr. Arif Inam, Reader Department** of Botany, Aligarh Muslim University, Aligarh, for his **able guidance and continued interest during the course of** this study. I am equally thankful to **Prof.M.M.R.K.Afridi** for constructive criticism and encouragement.

I wish to thank to the Chairman, Department of Botany, Aligarh Muslim University, Aligarh for providing research facilities.

Thanks are due to **Prof. Samiullah, Drs. Aqil Ahmad, M. Aslam Parvez, M.M.A. Khan, F. Mohammad,** Saood **Husain, Nafees A. Khan, Ozair Aziz** and **Mrs. Akhtar** Inam for their help and suggestions from time to time.

I place on record my sincere thanks to my colleagues, **Mr. Rajagopal, R.; Mr. M. Yahya, Mr.** Tauheed **Khan, Mr. Shamsul Hayat, Mr. Moinuddin Khan, Mr.** Habibur-Rehman, **Mr. Azhar Sajjad, Mr. Maqusud Manzar, Mrs. Kahkashan Tarannum, Mrs. Roshan Ara Shah** and **Mrs. Anees Fatima** for their co-operation during the preparation of this manuscript. I am also thankful to **Mr. G.A. Subramanyam** for his valuable suggestion during the data analysis.

Special mention must be made of my respected parents, brothers (specially my younger brother Dr. **Ikramul Haque**) and sisters for providing me constant encouragement and moral support at every stage of my work.

In the last, my hearty thanks are due to my husband, **Mr. Kafil Khan,** for his continued co-operation and patience.

December 28, 1993 **(NASREEN FATIMA)**

CHAPTER 1

INTRODUCTION

INTRODUCTION

Innovative improvement in the agro-techniques required for the cultivation of field crops, especially cereals, has paramount importance for under-developed countries, like India, where an alarming condition has been created lately mainly on account of " population explosion" and decrease in arable land due to rapid urbanisation and industrialisation. Another very important reason for the abnormal situation at the food front is the lack of financial capacity of the average Indian farmers to apply the required dose of fertilisers to their crops due to the spiralling prices of this scarce input. The crisis has deepened further with the " Green Revolution" depending on high yielding cultivars that require larger amounts of fertilisers for the realisation of their full genetic potential than those cultivated earlier. Another constraint in applying the requisite quantities of fertilisers to crops is the lack of irrigation facilities in our country. It is estimated that about 80% of our crops depend upon natural precipitation and cannot be grown with a single large dose of fertilisers applied at the time of sowing.

The Science Advisory Council of the Government of India has rightly urged the farm scientists recently to find ways and means to raise the annual food production level to 300 million tonnes by the end of this century to avoid the predicted food crisis at the beginning of the next century (Gupta, 1990).

One way to ensure high yield of a promising cultivar is to carry out prior systematic investigations on its optimum nutritional need as well as mode of fertiliser application under the regional climate where it is to be cultivated. Needless to add that although most of the essential nutrients are present in different quantities in available forms in Indian soils, crop yield is limited particularly by the three primary fertiliser nutrients NPK unless added regularly as these are removed in large quantities by crops. Soil fertility can, therefore, be maintained only by supplying these nutrients as fertilisers in adequate quantities as and when they are needed.

Of the essential and indispensable nutrients for all forms of life, including plants, phosphorus plays a major role through the genetic molecules (nucleic acids) and due to its function in energy transfer via adenosine triphosphate. In natural eco-systems, it is usually the life-limiting element because of its low availability. In general, the supply of soil phosphorus is often deficient for the growth of commercial plants. This deficiency can be overcome generally by applying phosphatic fertilisers, because phosphorus is not recycled in rainfall nor it is readily released from organic residues. Another alarming factor about this element is its limited world-wide quantity in the rocks that warrants judicious application and prevention of wastage.

It goes without saying that the yield of a crop depends on its vegetative as well as reproductive phase. Vegetative growth is characterised by the synthesis and organisation of new plant material into an expanding root and shoot system. Photosynthetic processes supply the growing plant with carbon skeletons that are incorporated into carbohydrates, proteins and lipids in addition to many other cytoplasmic and structural constituents, through a myriad of self-controlled reactions. These metabolic processes require adequate supplies of the essential inorganic nutrients. Like the vegetative growth phase, the reproductive phase of a cereal crop is dependent upon a number of morphological features such as, the number, weight and length of ears, the number and size of spikelets and the number and weight of grains. Of course, proper partitioning of the photosynthates between source and sink is equally important for viable agriculture.

The yield of a crop also depends on its genetic constitution and cultivar differences are of great significance, as the interaction between a cultivar and its surroundings profoundly influences crop yields. Among the various environmental conditions, availability and proper balance of essential nutrients is of paramount importance to ensure successful farming (Milthorpe and Moorby, 1979). The objective of comparative study of nutrient requirement for proper vegetative as well as reproductive growth and yield of a particular crop should, therefore, be the determination of cultivation practices for ensuring efficient use of applied fertiliser by selecting the best cultivar capable of extracting and utilising nutrients and other inputs effectively.

For centuries, farmers have applied fertilisers to the soil at the time of sowing. However, split application through top-dressing and more recently by spray application has attracted the attention of the entire farming world. These practices are recognised as a measure of fertiliser economy throughout the world. The nutrients generally applied to the leaf surfaces are absorbed, translocated and subsequently utilised in a similar way as the nutrients applied to the roots (Volk and Mc Auliffe, 1954). Compared to nitrogen and micro-nutrients, less work has been done on the foliar application of phosphorus. The nutrient is known to be easily absorbed and utilised from sprays and the amount required is much less than for soil application by top-dressing where practised (Boynton, 1954; Afridi and Wasiuddin, 1979).

Triticale is a hybrid of intergeneric cross between wheat (Triticum) and rye (Secale). It combines the high yielding ability and protein content of wheat with the high lysine content of rye. In addition, it also possesses the desirable quantity of drought- and disease-resistance of rye

(Hulse and Spurgeon, 1974; Baier, 1991). Thus, triticale is gaining acceptance by growers and consumers as the first man-made commercial cereal and it seems likely that, in future, it will compete successfully with the traditional cereals. At present, triticale is grown in about 52 countries and occupies over one million hectares of land around the world (Anomymous, 1986). Some of the triticale growing countries are Argentina, Australia, Brazil, Canada, Chile, China, Hungary, Mexico, South Africa, the former Soviet Union, Spain and the United States of America where several improved triticale cultivars have been released for commercial use (Anonymous, 1980, 1982). In our country too, interest is being developed in its cultivation and one cultivar (TL-419) was released during the 1980's for Punjab farmers. More recently, another improved cultivar of triticale (DT-46) has been released for cultivation in hilly regions.

Extensive research work has been conducted at Aligarh (India) for the last two decade by Afridi, Samiullah, Inam and their associates (Afridi et al., 1977; Inam, 1978; Abbas, 1980; Inam, et al., 1982 a,b; Abbas et al., 1983 a,b; Moinuddin et al., 1985; Ashfaq, 1986; Moinuddin, 1987, 1989; Moinuddin et al., 1990; Samiullah et al., 1991; Aziz, 1991; Inam, 1992; Inam et al., 1992) on triticale cultivars as and when they were released. It may, however, be admitted that not much work was conducted with reference to phosphorus application particularly in case of new high yielding cultivars having better yielding ability and quality in comparison with wheat (Inam, 1992).

Therefore, it was decided by the present author to conduct the following field trials on the phosphorus nutrition of selected high yielding cultivars of triticale :

1. To find out the effect of two doses of phosphorus applied basally (together with split application of nitrogen at sowing and tillering) on growth parameters, leaf-NRA, leaf-N, -P and -K contents, yield characteristics and grain quality of four cultivars of triticale and a popular wheat check to select the best cultivar.

2. To determine the suitable stage (or stages) of plant growth for the purpose of foliar spray of phosphorus in relation to yield and quality of the best performing triticale selected on the basis of the data of Experiment 1, retaining the wheat check for further comparison. Sub-optimal basal phosphorus would be applied retaining the nitrogen doses as in the previous experiment.

3. To select a good source of phosphorus for the cultivation of the best triticale sprayed at the stage(s) selected on the basis of Experiment 2, applying the same starter doses of basal nitrogen and phosphorus and that of nitrogen for top-dressing.

4. To test the flour of triticale for its colour, softness and flavour of loaf and chapatti, alone and in combination with wheat flour.

It is expected that the results would help increase the productivity of triticale, together with economy of phosphatic fertiliser, thus making it economically attractive for the farmer in addition to enhancing its grain and flour quality so as to be acceptable to the consumer.

CHAPTER 2

REVIEW OF LITERATURE

CONTENTS

REVIEW OF LITERATURE

2.1 Brief history of triticale

Today's flourishing triticale is just over a century old. It was in 1876 to be precise that Stephen Wilson, a Scottish scientist, reported the first successful cross between wheat and rye in the Transactions of the Edinburg Botanical Society. He carried out his crossing experiments by dusting the pollen from the rye plant upon the stigma of wheat. However, the few seeds from this historical genetic cross that germinated produced sterile plants. This finding encouraged other researchers to follow. Thus, in 1889, Rimpau of Germany described a spontaneously occurring, and interestingly partly fertile wheat-rye hybrid. Because of very low fertility and difficulty in obtaining viable seeds, this hybrid remained an academic curiosity for some time. Then after a gap of nearly half a century, in 1937 Pierre Givaudon of France treated the sterile seedlings with colchicine that resulted in a fertile triticale plant. This thrilling discovery, together with embryo culture techniques developed in 1940, opened the doors for the genetical, cytological, morphological and physiological changes in triticale leading to a potential grain crop (Jenkins, 1974; Muntzing, 1974; Zillinsky *et al.*, 1980; Inam, 1992).

At early stage, progress in the development of triticale remained slow because of some inherent problems like poor germinability, grain shrivelling, plant height leading to lodging, late maturity and sprouting (Zillinsky and Borlaug, 1971b).

In the beginning, triticale improvement programme was launched in Hungary in 1947 followed by other countries of Europe and North America (Anonymous, 1976a). Later an extensive and productive triticale research programme was undertaken at the University of Manitoba (Canada) in collaboration with the Centro Internacional de Mejoramiento de Maize Y Trigo (CIMMYT) stationed at Ciano (Mexico). This programme began in 1954 with the establishment of Rosner research chair in agronomy at the University of Manitoba. The triticale that had originated here showed remarkable hybrid vigour in Mexico but was late maturing, tall and bearing sterile seeds. However, between 1959 and 1962, due to extensive crossing among more fertile primary triticales, secondary triticales were produced. By 1967, some new cultivars of triticale had been developed that gave yields as high as standard cultivars of bread wheat in western Canada. Thereafter, modest production of triticale started at Manitoba, the better cultivars being grown under contract for fermentation and distilling industries. Some of the new cultivars also showed high potential as fodder crop. A new cultivar of triticale named " Rosner" was licensed for sale to farmers in Canada in 1970.

The First International Triticale Yield Nursery (ITYN) 1969-70 reported that the yield of the best triticale was only 75% of the yield of Pitic-62, a widely adopted dwarf bread wheat. Since then triticale improvement progressed so smoothly that the Fifth ITYN (1973-74) reported that it out-yielded wheat checks at many places (Anonymous, 1975).

It is interesting to mention that triticale is now under cultivation on commercial scale in many countries, including Argentina, Canada, China, Hungary, Mexico, South Africa, U.S.A. It is being grown over more than one million hectares in about 52 countries under varied environmental conditions, such as cold weather and soils that are light sandy or acidic (Hulse and Spurgeon, 1974; Anonymous, 1978a, 1982, 1986).

After a large number of trials on different aspects of this crop, the yield of the best triticales which was initially only upto half of that of bread wheat, has now been considerably improved so as to equal or even surpass the best wheats (Acosta, 1973; Chauhan and Bajpai, 1972; Upadhyaya, 1973; Kiss, 1974; Reddy and Lal, 1976; Afridi _et al_., 1977; Inam, 1978; Larter _et al_., 1978; Abbas, 1980; Ashfaq, 1986; Moinuddin, 1987; Aziz, 1991; Baier, 1991; Inam, 1992).

2.2 Phosphorus nutrition

Phosphorus stands second in order of requirement by crops. This element is found both in organic and inorganic forms in soils. It is absorbed by the plants from the soils as $H_2PO_4^-$, HPO_4^{--} or PO_4^{---} .

Besides entering into the conformation of the plant body as part of nucleic acids and phospholipids, phosphorus also affects various metabolic activities directly or indirectly. It is a constituents of coenzymes such as NAD, NADP and ATP which play an important role in various metabolic activities (Salisbury and Ross, 1991). It influences the vigour of plants and improves the quality of crops (Patnaik, 1987). It also increases lateral root, tiller and seed formation. Through its influence on the translocation of food to the seeds, it affects the process of seed filling and thus has a profound bearing on the economic yield of many crops. Phosphorus is also responsible for preventing lodging, which is frequently reported in triticale. It increases grain and straw yields and promotes disease resistance (Black, 1968). It probably plays an important role in the efficient functioning and utilisation of nitrogen in the plant (Wallace, 1961). Thus, its deficiency results in stunted growth, reduction in tiller and leaf number and decrease in the number and size of grain in cereals (Hewitt, 1963).

2.3 Fertiliser application

Application of fertilisers influences the productivity of soils as revealed by the crop yields obtained from them. The three primary plant macronutrients - N,- P and-K are removed by the crops in large quantity. This drain would impoverish the soil unless it is replenished by natural or artificial means. The principal methods of increasing the productive capacity of the soil are (i) addition of organic matter to the soils, which, through decay, it may furnish a more or less continuous but slow supply of nutrients for crops and (ii) provision of deficient nutrient by the application of commercially produced concentrated fertilisers.

A drawback with phosphatic fertilisers is that upto about 70-80% of the quantity applied to the soil at the time of sowing is soon made unavaible due to " fixation" and is, therefore, not available to the crops as they grow towards maturity (Russell, 1950). To ensure sufficient availability, top dressing or foliar spray may be necessary. However, the following review on the phosphate requirements of triticale reveals that hardly any work has been done on this aspect.

2.3.1 Phosphorus, growth and yield of triticale

The Hungarian scientist Kiss (1968), one of the pioneers among triticale researchers, worked out the fertiliser requirement of triticale. He concluded that the optimum phosphorus dose for triticale was 140 kg P (in addition to the same quantitity of N and K) per cad hold (1 cad hold = 0.57 hectare), given in two equal doses in autumn and spring.

At Ludhiana (Punjab, India), Anand (1972) conducted a cultivar trial taking ten triticale cultivars by applying a uniform dose of fertiliser at the rate of 29.5 kg P/ha (and 134.0 kg N/ha). He noted that four cultivars of triticale, namely Armadillo - 147, Armadillo-211, Armadillo-1524 and Bronco-90 outyielded the two wheat checks as well as the remaining triticale cultivars. The maximum grain yield was recorded in case of Armadillo-211 (42.77 q/ha) and the minimum (9.72 q/ha) in Bruim-34.

Chauhan and Bajpai (1972), while working at high altitudes of Kumaon hills (U.P., India), applied 30 kg P/ha (with 40 kg N and 20 kg K/ha) on acidic soils under rainfed conditions. They reported that Armadillo PPV-13 gave the maximum grain yield (29.9 q/ha) out of eleven triticales. This grain yield was surprisingly six times more than that of the wheat cultivar Kalyansona which recorded only 4.7 q/ha grain yield.

Gerek and Kutluk (1972) performed an experiment at Eskisehir (Turkey) without giving any irrigation and applying 26.4 kg P/ha (with 30 kg N/ha). They observed that triticale cultivars Bronco-90 gave the highest grain yield among triticales. Out of the 16 cultivars tested with four wheats and one barley, three cultivars of wheat gave lower grain yield than Bronco-90. However, they noted wheat cultivar Pitic-62 outyielded all the triticale and wheat cultivars.

Nasr and Guiragossian (1972), working in Lebanon, applied 35 kg P (in combination with 18.1 kg N/ha) and reported that most of the triticale cultivars tested gave higher yield than local check Najah. Except wheat cultivar Pitic-62 the other four cultivars of wheat were surpassed by Armadillo-130, Armadillo-136, Armadillo-146 and Armadillo-157 and Rosner cultivars of triticale.

Acosta (1973), in Morocco, tested twenty five triticale and wheat cultivars applying a uniform dose of 57 kg P (with 99.5 kg N and 39 kg K)/ha. It was observed that Badger PM-118 gave the maximum grain yield (36.2 q/ha) surpassing all the wheat cultivars. It was closely followed by another triticale cultivar Badger PM-112. It may be pointed out that in this study Pitic-62 wheat, generally considered a good yielder, produced only 22.8 q/ha.

Andrascik and Matusov (1973) compared the productivity of one cultivar of triticale with four of wheat at Nitra (Czechoslovakia). The fertiliser dose was given in various combinations of 105 or 150 kg P/ha (with 70 or 100 kg N/ha and 125 or 180 kg K/ha). They observed that maximum grain yield was given by 150 kg P with 100 kg N/ha and 180 kg K/ha. The highest yield (38.7 q/ha) was given by Mironovka (wheat) which was 8 q higher than those of other three wheat cultivars, while the triticale was the poorest yielder in this trial.

Kiss (1973) at Kecskemet (Hungary), applied 30 kg P (with 150 kg N and 29 kg K/ha) and noted that grain yield of all the triticale cultivars tested was higher than that of local cultivar Libellula and three other cultivars of wheat. He reported that Armadillo T-909 yielded 54.2 q/ha and proved the best among all the cultivars of triticale and wheat.

Fodor (1974) cultivated triticale together with _Vicia_ species of fodder crop on chernozem soil at Iregszemcse (Hungary) for consecutive three years and applied 60 kg P and 70 kg K/ha with nitrogen ranging from 0 to 160 kg/ha. Nitrogen showed positive correlation with green matter production. The most economical response was obtained from 80 kg N/ha when given in equal quantity at sowing and at early spring.

Reddy and Lal (1976) at Pantnagar (U.P., India), studied the response of triticale and wheat cultivars under unirrigated conditions to the application, of 30 kg P_2O_5 (in combination with 50 kg N/ha). Among the triticale cultivars, highest grain yield was noted in Armadillo PM-112, followed by Bronco-90. However, wheat cultivar C-306 proved the best among all the cultivars tested, recording upto 23.43 q/ha grain yield.

Afridi _et al_. (1977), working at Aligarh (U.P., India), applied 60 kg P_2O_5 (and 60 kg K_2O or together with three nitrogen levels, i.e. 90, 120 and 150 kg N/ha) to two cultivars each of wheat (HD-1982 and HD-2009) and triticale (Armadillo PPV-13 and Badger PM-119). They observed that the response to phosphorus (and potassium) application was best with the nitrogen dose 120 kg N/ha. Among the four cultivars tested, HD-1982 yielded the best. However, triticale cultivar Armadillo PPV-13 was at par with the locally popular wheat cultivar HD-2009 in grain production.

Andrascik and Licko (1977) studied the effectiveness of NPK with three cultivars of wheat, two of rye and one of triticale at Nitra (Czechoslovakia). They applied three rates of nitrogen, phosphorus and potassium (60:78:72, 100:130:120 and 140:182:168 kg/ha) with chlormequat. They noted annual yields for wheat cultivars upto 57.0 q/ha and for rye upto 49.0 q/ha. The grain yields for triticale were quite low going down to only 28.0 q/ha for all the combinations of NPK. Rye cultivars gave the highest yield with the lowest dose of NPK while higher rates proved detrimental.

Dhiman and Kalra (1977) working at Meerut (U.P., India), applied 25 kg each of P_2O_5 and K_2O/ha together with four levels of nitrogen (0, 25, 50 and 75 kg/ha) on triticale cultivar ST-69-1 and wheat cultivar Kalyansona during the years 1973-75. It was observed that in 1973-74 average grain and straw yields increased progressively with the increase in nitrogen level whereas maximum grain and straw yield was 26.80 q/ha and 69.00 q/ha respectively. Grain yield of wheat as well as of triticale cultivars was more or less at par in both the years, but the straw yield was 34.0% and 28.1% higher in triticale than in wheat in 1973-74 and 1974-75, respectively.

Bhardwaj and Agrawal (1978), working at Saharanpur (U.P., India) applied 40 kg each of phosphorus and potassium together with four levels of nitrogen (75, 100, 125 and 150 kg/ha) to two cultivars each of triticale (T-4, PC-202) and wheat (Kalyansona, Shera). They observed no significant effect of applied nitrogen doses at the level of phosphorus given either on wheat or on triticale. However, they noted that grain yield of triticale cultivar PC-202 was at par with that of wheat cultivar Kalyansona.

Inam (1978), while working for his doctoral thesis at Aligarh (U.P., India), which was subsequently abstracted (1982) and published in parts (Inam _et al_., 1982a, 1982b, 1985, 1992) observed the effect of nine combinations of NPK on the germination, leaf NPK content and yield components of three triticales i.e. Armadillo PPV-13, Armadillo T-15 and Badger PM-119. He noted that germination was adversely affected by fertiliser while nutrient content increased significantly by the application of fertiliser . $N_{120}P_{60}K_{60}$ recorded maximum values for nitrogen at all the stages. For phosphorus content $N_{90}P_{60}K_{30}$, $N_{120}P_{30}K_{30}$ and $N_{120}P_{60}K_{30}$ and for potassium $N_{120}P_{60}K_{60}$, $N_{90}P_{60}K_{30}$ and $N_{120}P_{60}K_{30}$ were most effective at tillering, heading and milky grain stages respectively. In general, yield and its components were significantly affected by nitrogen. It was noted that $N_{120}P_{60}K_{60}$ proved optimum for most of the yield parameters contributing to grain yield. Another combination $N_{120}P_{60}K_{30}$ also proved equally good for grain and straw yields. Among the cultivars Armadillo PPV-13 recorded maximum grain and straw yield.

Tahir (1978) studied the effect of fertiliser application on wheat, triticale and barley at Islamabad (Pakistan) The best wheat cultivar yielded 15.2 q/ha without fertiliser application and the yield increased upto 22.3 q/ha with the application of 60 kg P/ha+60 kg N/ha. He noted that phosphorus gave the best results when applied at first irrigation and that the optimum nitrogen dose was 168 kg/ha.

Bishnoi and Hughes (1979), working at Huntsville (Alabama, U.S.A.) in an extended study from 1973-75 on triticale, rye and wheat applied 40 kg each of N, P_2O_5 and K_2O/ha before sowing. In addition, they also applied 30 kg N/ha after each cut and also in late February and early March. In a two-fold study made on forage taken at four cuts, they recorded grain yields of 17.1, 12.4, 14.9 and 9.5 q/ha on uncut plots for winter triticale, intermediate cultivars of triticale, rye and wheat, respectively.

Kalra and Dhiman (1979), at Meerut (U.P., India) studied the response of wheat and triticale to 25 kg each of P_2O_5 and K_2O applied with four levels (0, 25, 50 and 75 kg N/ha) of nitrogen. They found that in 1973-74 average grain yields of wheat and triticale increased with increasing rates of nitrogen. Similar results were also obtained in the following trial conducted during 1974-75, but the difference between lower (25 kg N/ha) and higher (75 kg N/ha) doses was not significant.

Turbin *et al.* (1980), while working on spring triticale as a cover crop for herbage species in Moscow, applied fertiliser rates 100-120 kg N + 402-412 kg P_2O_5 + 440-460 kg K_2O/ha calculated for the targeted yields of the area i.e. 30.6-60.0 q/ha. They recorded the maximum grain yield in triticale when compared with wheat, barley and rye. The maximum fodder yield in triticale was 573.9 q/ha with 120-140 kg N + 412-424 kg P_2O_5 + 460-480 kg K_2O/ha and the maximum herbage yield of 357.6 q/ha with 80-90 kg N + 202-302 kg P_2O_5 + 400-420 kg K_2O/ha.

Ponce *et al.* (1981) studied the interaction of method of cultivation with different phosphorus, nitrogen and potassium fertiliser rates in two triticales at Chapingo (Mexico). They applied phosphorus ranging from 0 to 76 kg, nitrogen 0 to 115 kg and potassium 0 to 57 kg/ha and noted that grain yield was 25.8 q/ha with the application of 76 kg P_2O_5 + 88 kg N + 39 kg K_2O and 33.4 q/ha with 28 kg P_2O_5 + 61 kg N + 21 kg K_2O/ha. Grain yields were not significantly affected by fertiliser rates with different methods of cultivation. They also noted that grain yields were higher in triticale than in barley or oats.

Dimitrov *et al.* (1982) of Sofia (Bulgaria), while working on techniques for the cultivation of triticale, observed that 100 kg P_2O_5 (in presence of 120 kg N and 100 kg K_2O/ha), was the optimum fertiliser rate for triticale cultivar No.7291, although highest yields were recorded with 140 kg P_2O_5 + 180 kg N and 140 kg K_2O/ha.

Farnworth and Said (1982), at Damar (Yemen Arab Republic) studied the performance of triticale cultivar Beagle grown with 50 kg P_2O_5/ha and six levels of nitrogen (0, 50, 100, 150, 200 or 250 kg N/ha). It was observed that grain and total crop yield increased with increasing nitrogen application at the phosphorus level applied.

Prasad and Singh (1983) at New Delhi (India) studied the relative efficiency of triticale and spring wheat in utilising phosphate from different fertiliser sources varying in the amount and water solubility of phosphorus on sandy loam clay soil. Phosphorus was applied as ordinary superphosphate, nitrophosphate or rock phosphate at the rate of 45 or 90 kg P_2O_5/ha, in addition to 90 kg N and 90 kg K_2O/ha. Triticale had more fertile tillers, but lower 1,000 grain weight and more grains/ear compared with wheat. However, grain yield was 5.7 q/ha lower and straw yield was 4.6 q/ha higher than in wheat. It was also noted that although wheat plant did not show response to phosphorus application triticale responded well.

At Aligarh (U.P., India), Alvi (1984) observed the performance of triticale cultivars Armadillo PM-108 and Bronco-90 and compared it with that of wheat cultivar HD-1982 applying all possible combination of 13, 26 and 39 kg P/ha and 100, 150 and 200 kg N/ha, keeping N_0P_0 as control and adding 26 kg K/ha uniformly. He found that 26 kg P/ha with 200 kg N/ha proved optimum for most of the yield characteristics and gave 116% more grain yield than the control. Armadillo PM-108 gave 28% more grain yield than Bronco-90 and surpassed even the wheat check (HD-1982) in ear length, spikelet number/ear, 1,000 grain weight and straw yield, but its grain yield was only 80.5% of that of wheat.

Dimitrov (1985) grew a triticale cultivar (No. 7291) from 1982-84 at Sofia (Bulgaria) and applied 0 to 160 kg P_2O_5/ha and 120 to 200 kg N/ha in different combinations. It was noted that 160 kg P_2O_5/ha + 200 kg N gave the highest average grain yield of 59 q/ha compared with 33.5 q/ha without NPK. Addition of potassium to phosphorus and nitrogen gave no further significant increase in yield. Interestingly, the highest yield with phosphorus and nitrogen was 73 q/ha in 1982.

Moinuddin <u>et al</u>. (1985) and Moinuddin (1987) worked out the optimum NPK requirements, at Aligarh (U.P., India), of four cultivars of triticale, keeping one cultivar each of wheat and rye as check. All possible combinations of three levels each of phosphorus (30, 40 and 50 kg/ha) and nitrogen

(150, 200 and 250 kg N/ha) were applied and it was noted that 40 kg P/ha with 200 kg N/ha proved best for population count and for all growth, yield and quality parameters.

Ashfaq et al. (1984) and Ashfaq (1986), also working at Aligarh (U.P., India), applied 25 kg each of P and K/ha and varied the nitrogen doses, starting with as low as 0 kg N/ha and going upto as high as 300 kg N/ha, with a difference of 50 kg N/ha between each dose, and studied their comparative effect on two cultivars of triticale. She studied various yield parameters including grain and straw yield, and reported that, at the phosphorus dose taken, 150 kg N/ha gave the optimum results for most of the yield parameters.

Tabl and Kiss (1986), during two years experiments with two hexaploid triticale and two wheat cultivars in Hungary, studied the effect of 100 kg each of P and K applied with six doses of nitrogen on yield and its components. The number of spikelet/ear, number of grains/ear, grain weight/ear and ear length in triticale were significantly higher than in wheat. At the phosphorus (and potassium) level applied, the rate of nitrogen that proved optimum in the two triticale cultivars was 90 kg/ha while that for the two wheat cultivars was 120 kg N/ha.

Dziamba (1987), tested the effect of CCC (chlormequat) and fertiliser, on yield, its components, protein and lysine contents in the grains of triticale, wheat and rye in Poland during 1977-80. All the three cultivars were given 0, 150, 300 or 450 kg NPK and 2 or 4 kg chlormequat/ha. It was noted that 150 kg NPK gave the highest yields. Triticale had fewer fertile tillers, longer ears, higher grain yield/plant and higher grain protein contents than wheat or rye.

Samiullah et al. (1987), working at Aligarh (U.P.,India), studied the effect of phosphorus, nitrogen and potassium on growth characteristics of triticale at tillering, heading and milky grain stages of growth. They noted that fertiliser application favourably affected all growth characteristics. Armadillo PPV-13 performed best with respect to all growth characteristics at all the stages. In general, combinations containing 60 kg P/ha and 120 kg N/ha were more effective for most of the growth parameters.

Moinuddin et al. (1990), at Aligarh (U.P., India), studied the response of eight cultivars of triticale (Bronco-90, Badger PM-118, Delfin, Juppa 'S', Mula 'S' Muskox 'S', Tigre 'S' and TL-419) in comparison with wheat (HD-1982) and rye (Russian rye) with regard to NPK accumulation in the leaf, growth, yield and quality characteristics by the application of 30 kg each of P and K/ha and 150 kg N/ha. Delfin, closely followed by Tigre 'S', mostly gave maximum values for leaf-NPK, growth, yield and quality characteristics.

2.3.2 Phosphorus and grain quality of triticale

Cereals are the main staple food for most of the population of the world. In view of their nutritive value, they have been extensively studied by farm scientists. The nutritional value of a cereals protein is determined by its lysine content,one of the essential amino acids. Being a constituent of protein, nitrogen plays a key role as far as protein and essential amino acids of the cereals are concerned. As early as 1922, Gericke found that nitrogen was needed in sufficient amount at certain critical stages of growth and that the protein percentage of grain increased with late application of nitrogen.

Among the most studied cereals, wheat has been thoroughly investigated for its grain protein content as affected by nitrogen application (Primost, 1956; Wahhab and Hussain,1957; Schlehuber and Tucker, 1959; Austin and Miri, 1961; McNeal et al., 1963; Zenyuk, 1970; McNeal et al., 1971; Murti, 1972 and Sharma and Singh, 1973). The effect of fertilisers on the quality of triticale grain has however, been studied only by a few workers. The effect of nitrogen, for example has been studied by Kalra and Dhiman (1979); Fencik et al. (1980) and Pino and Rodrigues (1980).

Unlike the effect on growth and yield of triticale reviewed earlier, the effect of the phosphorus on the grain quality of triticale has been studied by fewer workers. These studies were frequently restricted to combined effect of the nutrients with nitrogen or as NPK, as is brought forth by the brief review of available literature that follows.

Cherginets et al. (1980) performed two field experiments on triticale and wheat during the years 1976 and 1977 at Moscow (U.S.S.R.). In 1976, they applied 120 kg P_2O_5 and 90 kg K_2O/ha and either 90 kg N/ha (in two splits) or 180 kg N/ha (in three splits), keeping a no nutrient control. They recorded an increase in triticale grain protein content from 13.3% without nitrogen, phosphorus and potassium to 14.4% and 15.6% in the 90 and 180 kg N/ha treatments respectively. In wheat, on the other hand, the increase was from 10.9% (without NPK) to 13.4% and 14.1% respectively. During the following year, the increase in protein content was from 12.6% (without NPK) to 13.4% and 14.1% respectively in triticale while in wheat, it increased from 9.9% (without NPK) to 10.4 and 11.7% respectively, showing the superiority of the higher dose of the nutrients.

In Bulgaria, Kolev and Khristov (1983), worked out the effect of increasing rate of fertiliser doses on grain yield and quality of three cultivars of triticale. They applied 60 to 120 kg P_2O_5, 80 to 160 kg N and 40 to 80 kg K_2O/ha in three combinations, with $N_0P_0K_0$ as control. They found that the optimum grain yields of triticale cultivars Polsko-7 and PS hero-16 were 56.6 and 52.2 q/ha respectively, compared with

54.7 q/ha of Sadovo-1. It was observed that with higher fertiliser rates, 1,000 grain weight of triticale decreased but the protein yield/ha increased when compared with the unfertilised control.

Alvi (1984) studied, at Aligarh (U.P., India), the quality of grain of triticale cultivars Armadillo PM-108 and Bronco-90 and compared it with that of wheat cultivar HD-1982 applying all possible combination of 13, 26 and 39 kg P/ha and 100, 150 and 200 kg N/ha. He noted that medium phosphorus i.e. 26 kg P_2O_5/ha and high nitrogen levels (200 kg N/ha)gave the highest grain protein contents (134.7% more than control). Increasing levels of nitrogen affected lysine concentration adversely. Application of phosphorus favoured grain carbohydrate content whereas that of nitrogen depleted it. He noted that application of 26 kg P/ha in combination with 200 kg N/ha outyielded all other combinations and improved grain quality (protein and lysine) of the cultivars most.

Dimitrov (1984) analysed the protein and lysine content in the grain of the Bulgarian triticale cultivar No.-7291 during 1981-82, including three autumn and one spring seedlings and three NPK fertiliser levels. Depending on conditions of growing, protein content of the cultivar varied from 11.92 to 18.93% or 15.96% on the average. This value was 15.38% for the autumn seedlings and 17.52% for the summer seedlings. Protein level increased by later seedling dates and high mineral fertiliser rates. Lysine content in grain protein was 2.84 to 3.94% being 3.34% on the average.

Vaulina (1987) conducted field trials during 1976-79 in the Moscow region of U.S.S.R. Triticale cultivar Amphidiploid-206 and winter wheat cultivar Mironovskaya-808 grown without fertiliser gave average grain yields of 22.2 and 27.2 q/ha and had grain protein contents of 12.0 and 10.1% respectively. Application of 90 kg N/ha, in the presence of phosphorus and potassium, increased yields to 31.7 q and 37.0 q/ha and protein content to 14.4 and 12.2% respectively, further increase in nitrogen rates was not effective.

Aziz (1991) made a comparative study on triticale cultivar Delfin and wheat cultivar HD-2204 with three doses of NPK ($N_{60}P_{30}K_{30}$, $N_{90}P_{45}K_{45}$ and $N_{120}P_{60}K_{60}$) at Aligarh (U.P., India). 120 kg N/ha with 60 kg/ha each of P_2O_5, potassium gave higher grain yield with higher protein content. He also noted that Delfin surpassed the wheat cultivar HD-2204 in grain production as well as grain protein content.

Admittedly, less work has been done on the phosphorus requirements of triticale than on its nitrogen requirement world-wide. Some of the publication on the latter aspect are those of Prohaszka <u>et al</u>. (1971) Hungary; Zillinsky and Borlaug (1971) Mexico; Lafever and Schmidt (1972) U.S.A.; Zillinsky and Lopiz (1973) Mexico; Mazurck and Mazurck (1974)

Poland; Nass *et al*. (1975) Canada; Agarwal (1977) India; Misra (1977) India; Ali and Rajput (1978) India; Etchevers and Morghan (1978) Chile; Gajardo *et al*. (1978) Chile; Zatko (1978) Czechoslavakia; Agarwal (1979) India; Bishnoi and Mugwira (1980) U.S.A.; Gajardo *et al*. (1981) Chile; Modi and Lal (1981) India; Graham *et al*. (1983) Australia; Pleshkov *et al*. (1983) U.S.S.R. and Bali *et al*. (1991) India.

2.4 Foliar spray of phosphorus

Generally, the required amount of mineral nutrients is applied to the soil at the time of sowing in the form of solid commercial grade fertilisers. Under such conditions, large portion of the nutrients is rendered unavailable to the crop at later stages of growth owing to various well known mechanism operating in the soil, including fixation, volatilisation, microbial degradation and leaching etc. As mentioned by Russell (1950), who claimed that, out of the total phosphorus applied, 70-80% becomes unavailable in the course of a crop season, which is an alarming loss to the farmers, particularly in developing countries where fertilisers are in short supply and, therefore, a costly input. In view of the natural wastage and the inability of an average Indian farmer to offset it by applying appropriate high basal fertiliser doses, net productivity in the country remains low.

Various methods have been recommended from time to time to economise on fertilisers on the one hand and to increase their efficacy on the other. One of the methods commonly adopted by the farmers is " foliar nutrition" which is recommended to meet the nutrient requirement of crop plants at critical periods of growth in the form of dilute solution of the required nutrients sprayed over the foliage.

According to Bould (1963), interest in the nutrition of plants through leaves goes back to 1803 when Forsyth used the technique for the first time. However, for more than a century, serious attempts remained confined only to the correction of certain nutritional plant diseases caused by a deficiency of the micronutrient elements.

The following review is restricted to publications on the use of phosphorus through foliar spray to supplement basal application.

Lewis (1936) sprayed lettuce leaves with solutions of phosphorus(as well as nitrogen and potassium) and noted their absorption. After more than a decade Silberstein and Wittwer (1951) reported that leaf application of phosphorus produced a definite growth response in maize and beans. They also compared the effect of various modes of application of phosphorus. Leaf-applied phosphorus was found to be utilised much more efficiently than when it was broadcast over the soil.

Yatazawa and Higashino (1953) noted that, after its spray, phosphorus accumulation occurred in growing parts of Brassica chinensis. They also noted that inorganic phosphorus got readily synthesized into organic compounds once it had entered the plant.

Yatazawa and Tai (1953) traced the path of leaf-spplied phosphorus in Brassica chinensis. Phosphorus absorbed through the leaves got converted to glucose-1-phosphate and fructose-6-phosphate within four hours of its absorption.

Not much work has been undertaken regarding the effect of phosphatic spray on various crop plants, although application of nitrogen and micronutrients has become a common practice. However, Afridi, Samiullah, Inam and their associates have launched on a project for the last two decades to test the efficacy of leaf-applied phosphorus in improving the yield and quality of various crops, including triticale. Samiullah (1971), Afridi and Samiullah (1973), Samiullah and Afridi (1975) and Qaseem et al. (1978) on barley; Khalique (1975) on maize and lettuce; Naqvi (1976), Naqvi et al. (1977), Afridi et al. (1978a), Parvaiz (1978a), Parvaiz et al. (1982), Samiullah et al. (1985), Mohammad et al. (1986a,b), on mustard; Afridi et al. (1978b), Inam (1978), Abbas (1980), Alvi (1984) and Ashfaq (1986) on triticale and wheat; Noor (1986) on radish and turnip; Akhtar et al. (1984); Khan (1988), on mungbean and lentil and Mohammad (1989) on linseed have done considerable and obtained encouraging results, confirming the advantages of supplemental foliar nutrition over the other conventional practices of nutrient application.

In the following pages, an effort has been made to review the available literature on the effect of supplemental application of phosphorus by foliar spray on the yield and quality of triticale.

Inam (1978) and Inam *et al.*, 1992 working at Aligarh (U.P., India), sprayed three doses of 0.2% sodium dihydrogen orthophosphate solution (1, 2 and 4 kg P_2O_5/ha) on the foliage of triticale cultivar Armadillo PPV-13 grown with three basal doses of nitrogen (90, 120 and 150 kg N/ha) in combination with a uniform basal dose of potassium (60 kg K_2O/ha) and phosphorus (60 kg P_2O_5/ha). He reported that spray of 2 kg P_2O_5/ha at milky grain stage proved best for most of the yield attributes. However, straw yield was highest as a result of the spray of 4 kg P_2O_5/ha. The combination N_{150} x 2 kg P_2O_5 spray/ha gave the highest value for most yield characteristics but for grain yield N_{150} x 4 kg P_2O_5 spray/ha was equally effective.

In another field trial on Armadillo PPV-13, he observed the effect of spray of 2 kg P_2O_5/ha singly and in combination with 20 kg N/ha with three nitrogen levels applied basally (90, 120 and 150 kg N/ha) in combination with a uniform basal doses of potassium (60 kg K_2O/ha) and phosphorus (60 kg P_2O_5/ha) on yield attributes. He sprayed an aqueous solution of 0.2% sodium dihydrogen orthophosphate with or without 2.0% urea at milky grain stage of growth. Spray of phosphorus together with nitrogen gave the maximum yield, followed by the spray of phosphorus alone. The combination N_{150} x N+P spray gave maximum value for most of the yield characteristics, followed by N_{150} x P spray.

Sayed and Al-Saad (1979) in a two year field trial conducted at Riyadh (Kingdom of Saudi Arabia) to study the effect of foliar application of nutrients on grain yield and quality of two triticale lines, namely (a) Armadillo x 308-3N and (b) Beaver x Armadillo x 2458-OY-111 and a wheat cultivar Mexipak-65, sprayed nitrogen and phosphorus nitrogen and potassium or nitrogen, phosphorus and potassium, with water as control. In each operation, 4.73 l/ha of 10% nitrogen, 12% P_2O_5 and/or 6% K_2O was sprayed. The average grain yields noted by them for Armadillo x 308-3N and Beaver x Armadillo x 2458-OY-111 cultivars of triticale were 14.5 and 16.5% less respectively than that for Mexipak-65 wheat. Hecto-liter weight and 1,000 grain weight were higher in triticale line Armadillo x 308-3N than in Beaver x Armadillo x 2458-OY-111 or wheat. They also reported that grain yield was increased by fertiliser treatments but the effect varied, depending on the year. Grain nitrogen, phosphorus and potassium and crude protein contents averaged 2.35%, 0.25%, 0.54% and 13.4% in

Armadillo x 308-3N and 2.23%, 0.24%, 0.55% and 12.71% in Beaver x Armadillo x 2458-OY-111 line respectively.

Abbas (1980) with the aim of fertiliser economy conducted a field experiment at Aligarh (U.P., India) using dilute aerial sprays of three sources of phosphorus, namely sodium dihydrogen orthophosphate, calcium superphosphate and diammonium phosphate at the rate of 5 kg P_2O_5/ha alone or in combination with two doses of urea (2 or 20 kg N/ha) to study the yield characteristics of triticale cultivar Badger PM-118 and wheat cultivar Sonalika. He noted that sodium dihydrogen orthophosphate proved the best source of phosphorus spray in the presence of 2 kg N/ha for most of the yield characteristics including grain yield, followed by sodium dihydrogen orthophosphate + 20 kg N/ha. He also found that triticale gave higher values than wheat for most of the yield characteristics, except 1,000 grain weight and grain yield.

Alvi (1984), also working at Aligarh (U.P., India), tested the effect of one or two sprays of phosphorus (0.2% sodium dihydrogen orthophosphate) and nitrogen as 2.0% urea on two triticales (Armadillo PM-108 and Bronco-90) and one wheat (HD-1982) and found that all spray treatments proved better than the water-sprayed control for most of the characteristics, including grain yield. Split spray of nitrogen and phosphorus (equalled by split spray of nitrogen), resulted in maximum increase of about 10% in grain yield.

Regarding interaction effect, each cultivar gave maximum response to phosphorus + nitrogen spray (equalled by nitrogen spray) with regard to most of the yield and quality characteristics. In fact split spray of phosphorus + nitrogen (as also of nitrogen alone) enhanced the grain yield of Armadillo PM-108 to such an extent that it almost reached parity with the wheat check (HD-1982) grown with an equavalent fertiliser dose supplied through conventional soil application only.

2.5 Baking quality

Of late, there has been some thinking on the part of some farm scientists to replace the wheat by the triticale, because it can be grown under a wider range of soil and climatic condition, like soil acidity (Slootmaker, 1974) ecological adoptability (Kohli, 1973; Kudryavtseva, 1977), adaptability to drought (Gregory, 1974; Stankova and Matsov, 1982), frost resistance (Stepochken and Vladimisov, 1985) and tolerance to salinity (Touraine and Meimoun, 1985).

Seed shrivelling in triticale was one of the major factors in achieving desirable industrial quality standards. However, with a remarkable increase in grain plumpness and test weight in present day triticales, appreciable improvement can be seen now in this field. Another impediment in wholesale adoption of triticale has been due to early reports by various investigators indicating that it was difficult to make satisfactory bread using triticale flour (Rooney et al., 1969; Bush and Wilkins, 1972). However, encouraging reports have been published during the same period by Tsen et al. (1971), at Kansas State Manhattan University, (Kansas, U.S.A.) and Lorenz et al. (1972), at Colorado State University Fort Collins (Colorado, U.S.A.) that it is possible to produce bread of acceptable quality with 100% triticale flour.

In 1972, priliminary baking studies made on several advanced hexaploid triticale cultivars at the CIMMYT Wheat Quality Laboratory Ciano (Mexico) proved quite satisfactory. Triticale flour was taken for the preparation of chapattis and it was noted that the quality characteristics of triticale and wheat chapattis were similar, except that the colour was darker in triticale chapattis (Anonymous, 1972).

A study was conducted by Berova (1974), at Sofia (Bulgaria) on the chemical, technological and baking qualities of one octoploid triticale (ADSOS-3-2) and four hexaploid forms (AD-30, AD-57, 102 NAD-137 and AD Canada-6643). It was noted that the highest content of protein (higher than wheat) and gluten (lower than wheat) was possessed by ADSOS-3-2 and 102 NAD-137. In tests of various mixtures of wheat and triticale flour, best results were obtained by adding the wheat flour upto 40% to the flour of AD-30 or AD-57, and about 50-60% of wheat flour to the flour of the other two cultivars.

Kozmina *et al*. (1976), while working in USSR, observed that two triticales had higher amylatic activity than wheat and rye. They also noted that in content of water soluble substances triticales resembled rye while in loaf size they matched wheat.

However, contrary to the above finding, Ivano and Prokopenko (1976) at Uman (Ukrainian SSR) compared the hexaploid and octoploid forms of triticale and noted that bread making quality was lower in hexaploid triticale samples than in octoploid ones.

In baking tests conducted at CIMMYT, Ciano (Mexico) a large number of triticale cultivars had bread volumes upto 700 c.c. in comparison with the bread wheat Yecora which had a loaf volume of 765 c.c. Triticale performed satisfactorily when its flour was used for making tortillas. Some cultivars of triticale provided flour which was better for cookies than the flour of bread wheat. Triticale flour used for making chapatti kept moist longer (and, therefore, soft) than those made from bread wheat flour which is a good property for keeping purposes (Anonymous, 1976b).

In 1977, CIMMYT Milling and Baking Laboratory at El Batan, (Mexico) improved the triticale flour extraction percentage which can be an important economic factor for the milling industry. It has improved quite close to wheat cultivars from an earlier less than 60% to over 65% in general and upto 70% in specific cases. Regarding the baking quality, when the triticale flour was used in mixture with bread wheat flour, good quality bread with high volume was obtained with 60% triticale and 40% wheat flour and even with 75% triticale and 25% wheat. Other food products such as flat unleavened breads like tortilla and chapattis or cakes, cookies and many other local types of breads were satisfactorily prepared from triticale flour (Anonymous, 1977).

Riman and Rakoczi (1977) evaluated the milling and baking quality of 21 winter triticale cultivars at Piestany (Czechoslovakia) and compared with those of winter wheat (Mironovska, Kaukaz), winter rye (Ceska), spring wheat (Zlatka) spring rye (Tesovska) and one cultivar of spring triticale. They concluded that the quality of triticale was equal to or slightly better than that of rye. However, it could not match the wheat.

Sharma et al. (1977) evaluated the chapatti making qualities of triticale on the basis of protein content, dry gluten content, maltose content and diastatic activity at Jabalpur (M.P., India). They found that cultivars JNK6T-002 and JNK6T-139 proved best out of eight cultivars tested for chapatti making.

Baking quality of triticale cultivars PM-498, 499, 500, 501, 502, 503, 504, 505, 506, 507, 508, and PM-509 was compared at CIMMYT, El Batan (Mexico) with the wheat cultivars Pavon-76, Pima-77 and Hermosillo-77 at 25%, 50% and 75% and compared with loaves of bread made from 100% wheat and 100% triticale flours. Interestingly, the quality of the bread prepared with triticale-wheat mixture was satisfactory and it was noted that the loaf volume of the mixture was even higher in some cases than the loaf volume of the 100% wheat or triticale breads. Mention has been made of mixture of Hermosillo-77 (wheat) and triticale which produced consistently good quality breads (Anonymous, 1978b).

Saurer and Dormann (1979) studied the baking quality of triticale in Switzerland. They noted that three French triticales (INRA-5, INRA-15 and Cormont) were generally intermediate in quality between rye (Petkus) and wheat (Zenith). They suggested that upto 20% triticale flour could be added to wheat flour without having any unwholesome effect, giving bread with improved flavour and better keeping quality.

At the University of Manitoba, Winnipeg (Canada), Bushuk (1980) studied the baking quality of triticale and found that it was very close in baking performance to that of wheat than the early cultivars of triticale.

Zillinsky *et al*. (1980) released at CIMMYT, Londres (Mexico) fourteen spring cultivars of triticale during 1978 and 1979 as a result of cooperative programme between CIMMYT and other countries. In 1977-78 breeding, cultivars in Mexico had test weight ranging from 65 to 78.6 kg/hl with an average of 72.0 kg/hl. They further reported that some of the best among the new triticales cultivars approached the level of good bread wheat cultivars in flour extraction.

While comparing triticale and wheat at CIMMYT, Ciano (Mexico), it was reported that most of the food products made from wheat flour could be successfully made from pure triticale flour also, including fermented and non-fermented dough products. For fermented doughs, where higher level of gluten was critical, triticales lagged behind of bread wheats in bread making qualities. However, for non-fermented dough products, such as chapattis and unleavened bread, triticale and wheat were at par. It was also noted that triticale flour might be used successfully mixed with wheat flour in the ratio upto 75% triticale and 25% wheat flour for good quality bread making. It was opined that triticale flour some-times acts in a synergetic manner when added to wheat flour, and the mixture of the two flours gives a better product than either used alone. In some cases, the loaf volume of bread made with triticale-wheat flour mixture was higher than that of the loaf with 100% wheat flour (Anonymous, 1982).

Brilhante and Baptista (1982) analysed a range of characteristics in 18 triticale cultivar grown with wheat and rye at Lisbon (Portugal). They noted that mean and maximum hecto-litre weight was low in triticale although it surpassed the wheat and rye in crude protein and flour yields. However, in most of the baking quality characteristics, the triticales were inferior to the wheat, but most of them equalled*the latter in loaf volume. Of the five highest-yielding cultivars, Beagle was low in baking quality but Rahum was among the best while the other three cultivars were acceptable.

Chawla and Kapoor (1983) studied the baking quality and acceptability of wheat-triticale chapattis at Hissar (Haryana, India). They prepared chapattis by substituting different proportions of flour from the wheat cultivar WH-157 with flour from each of the flour triticale cultivars. They noted that increase in the amount of triticale flour was responsible for the decrease in mean scores for physical and sensory characteristics. They, however, noted that the chapattis containing upto 40% TL-183 and THS-9, upto 50% JNK6T-229 and upto 30% URT-217 flour were acceptable.

2.6 Conclusion

It may be concluded from the above review that, in view of its late recogniton as a commercial crop, triticale needs more attention for proper exploitation of the genetic pool available at present. Recently, information regarding the origin and performance was reviewed by Inam (1992), who has pointed out that some mineral nutritional aspects of triticale, specially in relation to phosphorus nutrition, still remain to be investigated. Work on the efficacy of basal and foliar nutrition of new triticale cultivars as and when they are released should also continue.

Regarding the baking quality, it may be concluded that the present triticales are bridging the gap with bread wheat in flour extraction and in baking quality, except the colour of the flour and baked material like tortilla, chapatti etc. which requires more attention to make the crop and its products more acceptable to the farmers and consumers.

CHAPTER 3

MATERIALS AND METHODS

CONTENTS

MATERIALS AND METHODS

The three field experiments reported in this thesis were conducted during the 'rabi' (winter) season of 1988-91 at the Experimental Farm - cum-Botanical Garden of the Aligarh Muslim University, Aligarh (U.P.) India. The aim of these experiments was to study the effect of phosphorus applied basally and through foliage on growth, yield and quality parameters of improved triticale cultivars Delfin, Driera, TL-419, Tigre 'S'. Wheat (cultivar HD-2204) was taken as check. Crop response was assessed at three stages, i.e. tillering, heading and milky grain in Experiment 1. Yield and quality characteristics were studied at harvest in all three experiments. In addition, baking quality of triticale was also studied in comparison with wheat.

3.1 Agro-climatic conditions of Aligarh

Aligarh is situated at 27°53'N latitude, 78°51'E longitude and 187.45 m altitude. It has semi-arid and sub-tropical climate with hot dry summers and cold winters, the characteristic climate of Western Uttar Pradesh. The winter starts from October and extends upto March, with December and January being the coldest months. The mean temperature for December and January is about 15.0°C and 13.0° C with an extreme minimum record of 5.0°C and 2.0°C, respectively. Frost does not occur frequently and is not intense. During summer, the average temperature for the hottest months, i.e. May and June is 34°C and 37°C, with an extreme maximum record of 42°C and 45°C, respectively (Fig. 1). The average annual rainfall of Aligarh district is given in Fig. 2, while the average monthly rainfall at Aligarh is given in Fig. 3. More than 85% of the total rainfall of the year occurs during June to September and about 10% occurs in winter.

3.2 Soil characteristics

Soil samples from the experimental field were collected randomly before the sowing of each experiment from a depth of about 15 cm. Composite soil samples were prepared by mixing them. These samples were then analysed for testing the physico-chemical characteristics in the Soil Chemistry Laboratory of the Department of Civil Engineering, Aligarh Muslim University, Aligarh (U.P.), India. The relevant data for each experiment are given in Table 1.

3.3 Field preparation

Before each experiment, soil was thoroughly ploughed upto a depth of 15-25 cm to ensure maximum soil aeration and complete removal of weeds. Standard agro-techniques, recommended for the cultivation of cereals, were employed for preparing a well levelled and weed-free field with the required number of experimental plots. A light irrigation was given before sowing to ensure proper moisture content in

ALIGARH
TEMPERATURE VARIATION BY MONTHS

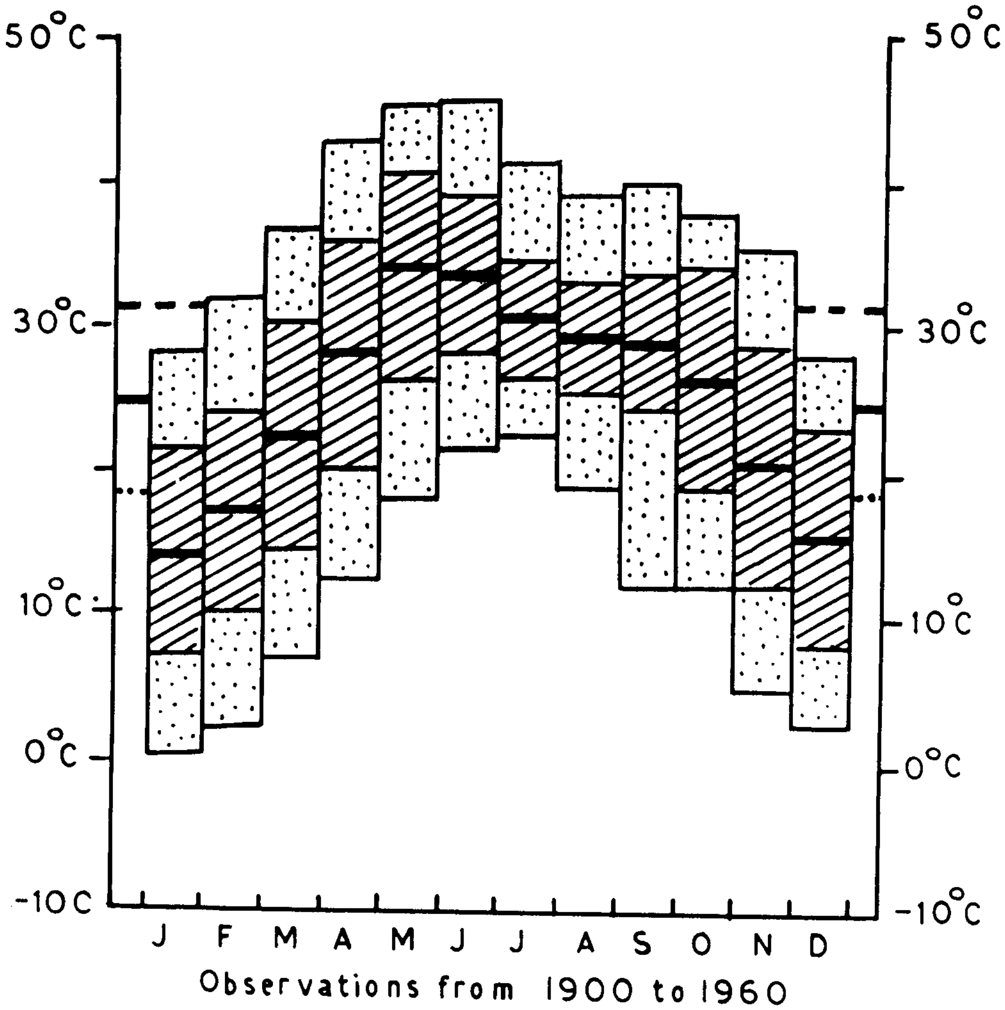
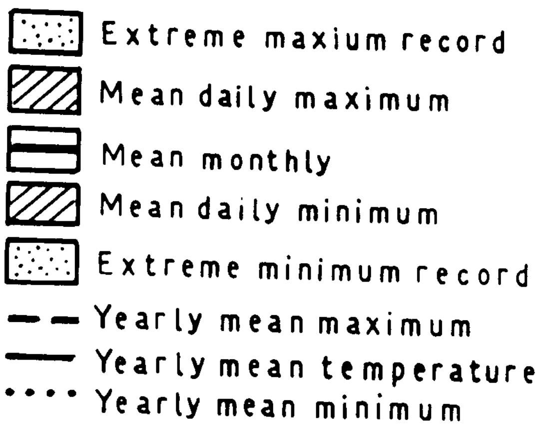
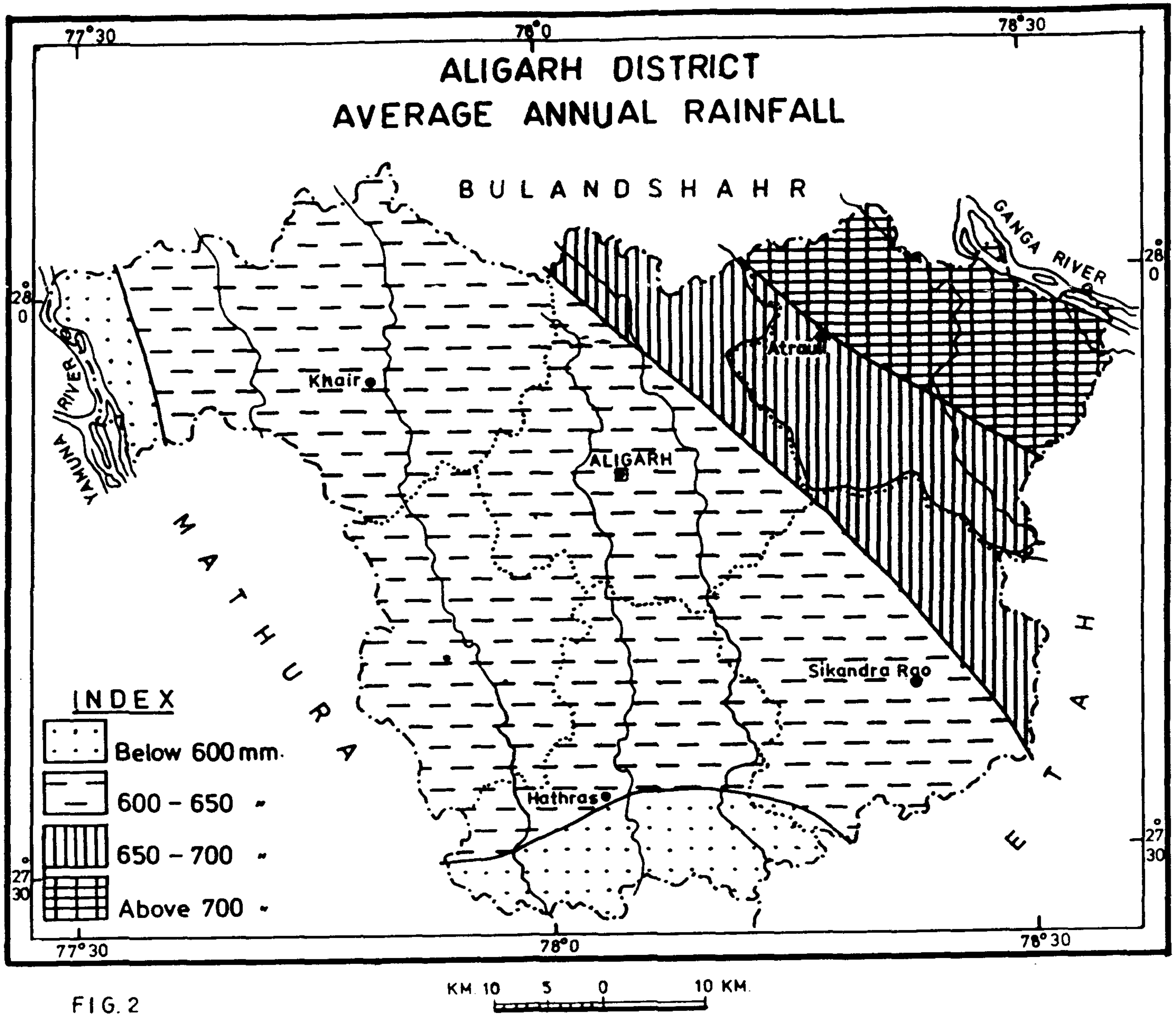


FIG.1





ALIGARH DISTRICT
AVERAGE ANNUAL RAINFALL
77°30
78°0
78°30
28° 0
27° 30
BULANDSHAHR
GANGA RIVER
YAMUNA RIVER
MATHURA
ETAH
Khair
ALIGARH
Atrauli
Sikandra Rao
Hathras
INDEX
Below 600 mm.
600 - 650 "
650 - 700 "
Above 700 "
KM 10 5 0 10 KM.

FIG. 2

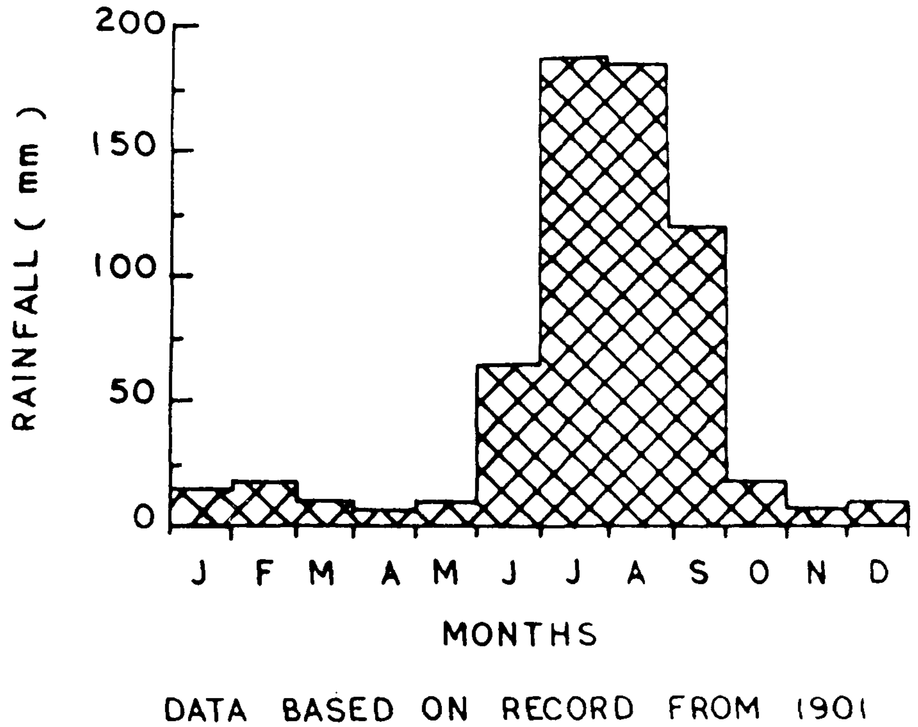


FIG. 3. AVERAGE MONTHLY RAINFALL AT ALIGARH

Table 1. Physico-chemical characteristics of the surface soil (Experiments 1-3)

Characteristics	Experiment 1 (1988-89)	Experiment 2 (1989-90)	Experiment 3 (1990-91)
Texture	Sandy loam	Sandy loam	Sandy loam
Sand (%)	50.54	51.00	52.00
Silt (%)	35.50	36.00	35.00
Clay (%)	13.00	12.50	12.00
pH	7.60	8.30	8.50
E.C. (m mhos/cm)	0.37	0.41	0.35
Available N (kg/ha)	206.00	195.00	175.00
Available P (kg/ha)	37.50	36.00	36.50
Available K (kg/ha)	750.00	730.00	745.00
Calcium carbonate	Low	Low	Low

the sub-surface of the soil. Prior to sowing, properly decomposed organic manures was mixed in each plot.

The details of each experiment is given in the following paragraphs:

3.4 Experiment 1

The first field trial was conducted in the 'rabi' season of 1988-89. The aim of this exploratory factorial randomised experiment was to compare the response of four cultivars of triticale and a locally popular wheat check to two doses of basal phosphorus, on the basis of growth parameters, leaf NRA, leaf-N,-P and -K contents, yield characteristics and grain quality. The rates of applied phosphorus were 45 and 60 kg P_2O_5/ ha. A uniform dose of 30 kg K/ha was applied at sowing. Nitrogen was given in two splits. At the time of sowing, 100 kg N/ha was applied uniformly. However, at tillering, an additional 50 kg N/ha was added in half of the experimental plots. Therefore, the plots received either $N_{100}P_{45}K_{30}$ or $N_{100}P_{60}K_{30}$ till the time of tillering and $N_{100}P_{45}K_{30}$, N_{100},$P_{60}K_{30}$, $N_{100+50}P_{45}K_{30}$ or $N_{100+50}P_{60}K_{30}$ thereafter. Nitrogen, phosphorus and potassium were applied in the form of commercial grade urea, calcium super-phosphate and muriate of potash, respectively. The summary of the treatment is given in Table 2. Thus, there were four treatments and five cultivars (one of wheat HD-2204 and four of triticale - Delfin, Driera, TL-419, Tigre's) with

Table 2. Summary of treatments (Experiment 1)

Cultivars	Sowing					Tillering						
	Treatments (kg/ha)											
	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
Wheat	100	45	100	60	100	45	100	60	100+50	45	100+50	60
Delfin	100	45	100	60	100	45	100	60	100+50	45	100+50	60
Driera	100	45	100	60	100	45	100	60	100+50	45	100+50	60
TL-419	100	45	100	60	100	45	100	60	100+50	45	100+50	60
Tigre'S'	100	45	100	60	100	45	100	60	100+50	45	100+50	60

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

three replications. The size of the plot was 5 sq m (2m x 2.5m). Before sowing, the seeds were tested for their viability and surface-sterilised with absolute alcohol. The seed rate was 100 kg/ha. The rows were kept at a distance of 20 cm from one another. The date of sowing was 10th November, 1988. The method of sowing was " behind the plough" . The field received three irrigations upto crop maturation. Weeding was done when required. The crop was harvested on 18th April, 1989.

3.5 Experiment 2

This field trial was conducted on the basis of the findings of Experiment 1, during the 'rabi' season of 1989-90. The Physico-chemical analysis of the soil is given in Table 1.

The design of the experiment was factorial randomised. The aim of this experiment was to determine the most suitable stage(s) of growth for the purpose of spray of phosphorus to optimise the yield and quality of Delfin, that performed best in the earlier experiment among the triticale cultivars. For comparison, wheat cultivar HD-2204 was retained as check.

The plants were sprayed at tillering (T), heading (H), milky grain (M), tillering and heading (TH), tillering and milky grain (TM), heading and milky grain (HM) and tillering, heading and milky grain (THM). The control was sprayed with de-ionised water. Thus, there were eight treatments (Table 3). Each treatment was replicated three times. The total quantity

Table 3. Summary of treatments (Experiment 2)

Treatments		Remarks
Control	(C)	Spray of de-ionised water
Tillering	(T)	Spray of 4 kg P/ha at tillering stage.
Heading	(H)	Spray of 4 kg P/ha at heading stage
Milky grain	(M)	Spray of 4 kg P/ha at milky grain stage
Tillering+Heading	(TH)	Spray of 4 kg P/ha in 2 equal splits at tillering and heading stages
Tillering+Milky grain	(TM)	Spray of 4 kg P/ha in 2 equal splits at tillering and milky grain stage
Heading+Milky grain	(HM)	Spray of 4 kg P/ha in 2 equal splits at heading and milky grain stages
Tillering+Heading+ Milky grain	(THM)	Spray of 4 kg P/ha in 3 equal splits at tillering heading and milky grain stages

N.B. A uniform basal dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied to triticale cv. Delfin at the time of sowing and 50 kg N/ha as top-dressing at tillering. Wheat cv. HD-2204 was taken as check.

of phosphorus applied in the form of monocalcium superphosphate sprayed as a 0.2% solution in all treatment was 4 kg P/ha (Table 3). This source of phosphorus was selected in view of its inexpensive nature and ready availability to the farmers.

The field was supplied with a uniform basal dose of nitrogen (100 kg N/ha), phosphorus (45 kg P_2O_5/ha) and potassium (30 kg K/ha), with another 50 kg N/ha added as top-dressing at tillering. NPK were applied in the form of urea, monocalcium superphosphate and muriate of potash respectively. The size of each plot was 5 sq m (2m x 2.5m). The date of sowing was 10th November, 1989. The space between the rows was 20 cm. The seeds were sown by the method of " behind the plough" and seed rate was maintained at 100 kg/ha. The field received three irrigations between sowing and harvesting. Weeding was done as and when required. The crop was harvested on 16th April, 1990.

3.6 Experiment 3

This last field trial was conducted in the 'rabi' season of 1990-91. The physico-chemical analysis of the surface soil of the field is given in Table 1.

The aim of this simple randomised experiment was to confirm the results of Experiment 2 on triticale cultivar Delfin. In addition observing the response regarding yield and yield attributes of this cultivar to foliar application of monocalcium superphosphate, two other sources of phosphorus, namely sodium dihydrogen orthophosphate and diammonium phosphate, were included in the spray treatments for comparison. The foliar sprays were applied at heading and milky grain stages, which proved ideal in Experiment 2, at the rate of 4 kg P/ha in the form of 0.2% aqueous solution applied in two equal splits. The control was sprayed with de-ionised water (Table 4). The wheat check was discarded in this experiment as it had repeatedly proved inferior in performance to Delfin.

The crop was grown with a uniform basal dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha, with another 50 kg N/ha applied as top-dressing at tillering, as in Experiment 2. The plot size was increased to 10 sq m (4m x 2.5m). The seeds were sown by dibbling, putting one seed at a fixed distance from the other, and, therefore, the seed rate was reduced to 40 kg/ha. Before sowing, the seeds were tested for their viability and surface-sterilised with absolute alcohol. The space between the rows was kept the same (20 cm) as in the previous experiments. Sowing was done on 10th November, 1990. The field was irrigated three times and weeded twice. The crop was harvested on 16th April, 1991. After harvesting, yield characteristics were noted and grain quality was analysed.

3.7 Sampling technique

Three plants from each replicate were taken randomly at tillering, heading and milky grain stages of crop growth

Table 4. Summary of treatments (Experiment 3)

Treatments	Remarks
Control	Spray of de-ionised water
Monocalcium superphosphate	Spray of 4 kg P/ha applied in 2 equal splits at heading and milky grain stages
Sodiumdihydrogen orthophosphate	-do-
Diammonium phosphate	-do-

N.B. A uniform basal dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha followed by 50 kg N/ha added as top-dressing at tillering. Triticale cv. Delfin was grown as the test crop.

for the study of growth characteristics, leaf NRA and leaf NPK contents in Experiment 1. Yield characteristics and grain quality were noted after harvest in all the three experiments.

3.7.1 Growth characteristics

To determine the effect of the treatments on growth of the plant, the following parameters were selected:

(i) Shoot length/plant

(ii) Tiller number/plant

(iii) Leaf number/plant

(iv) Fresh weight/plant

(v) Dry weight/plant

Growth analysis is a useful tool in studying the complex interaction between plant growth and the environment. The exercise is simple as the measurements do not require elaborate techniques. Whereas the fresh and dry weight would account for total productivity in terms of increase in weight, volume and dry matter accumulation, leaf number would be a measure of differentiation and tiller number of meristimatic activity. Each of these parameters would thus throw " light on some fundamental physiological process" (Gregory, 1937).

3.7.2 Yield characteristics

The following yield parameters were noted in all the three experiments at the time of harvest to assess the final yield response of the crop to the treatments:

(i) Ear number/plant

(ii) Ear weight/plant

(iii) Length/ear

(iv) Spikelet number/ear

(v) Grain number/ear

(vi) 1,000 grain weight

(vii) Grain yield/ha

(viii) Straw yield/ha.

3.8 Quality characteristics

The following grain quality parameters were estimated interms of percentage:

(i) Soluble protein

(ii) Insoluble protein

(iii) Total protein

(iv) Soluble carbohydrate

(v) Insoluble carbohydrate

(vi) Total carbohydrate.

3.9 Chemical analysis

For the estimation of leaf nitrogen, phosphorus and potassium contents, leaf samples were collected randomly at each growth stage and their oven dried powder analysed according to standard methods, while leaf NRA was estimated in fresh leaves.

3.10 Leaf-nitrate reductase activity (NRA)

It was determined according to the method of Jaworski (1971). For the estimation of NRA, fresh leaf material of each of three randomly selected plants was taken at tillering, heading and milky grain stages.

Fresh leaves were cut into small pieces. 500 mg of leaf pieces was weighed from each sample and transferred to 10 ml polythene vials. 2.5 ml of phosphatic buffer (pH 7.5) and 0.5 ml of 0.2M potassium nitrate solution was added followed by the addition of 2.5 ml 5% isopropanol. Two drops of chloramphenicol were added to avoid bacterial growth in the test medium. For the manifestation of enzyme activity, these vials were incubated for 2 hours in the dark at 30°C.

After incubation, 0.4 ml of test extract was taken in a test tube and 0.3 ml of 1% sulphanilamide solution, followed by 0.02% of N-1-napthyl-ethylene diamine hydrochloride (NED HCl), solution was added. The test set was left for 20 minutes for maximum colour development. The contents were diluted to a volume of 5 ml with distilled water. The optical density of this solution was read at 540 nm by using Baush and Lomb " Spectronic 20" colorimeter. A blank was run simultaneously. The optical density of each sample was compared with standard curve, plotted by taking various known dilutions of potassium nitrate. NRA was calculated in μ mole NO_2^-/h/g (fresh leaf tissue).

3.11 Estimation of leaf-N,-P and -K content

The N, P and K contents of the leaf were estimated by the following method:

3.11.1 Digestion of the sample

Each leaf sample was dried in an oven at 80°C for about 24 h. The dried sample was powdered and passed through a 72 mesh sieve. The powder was sprayed over a clean sheet of paper and left overnight in an oven at 80°C and cooled in a descicator for 15 min before digestion.

The digestion of the powdered leaf was done according to the method of Lindner (1944). For this purpose, 100 mg of the dried powder was carefully transferred to a 100 ml Kjeldhal flask and 2 ml of chemically pure concentrated sulphuric acid was added. The contents of each flask were heated for 2 h on a Kjeldhal assembly to complete reduction of nitrates present in the plant material. The flasks were cooled when the plant material turned to brownish-black, followed by dropwise addition of 0.5 ml of chemically pure 30% hydrogen peroxide. The solution was heated again for about 0.5 hour till its colour changed from brownish-black to light yellow. The flasks were then cooled and an additional amount of 3-4 drops of 30% hydrogen peroxide was added, followed by gentle heating for another 15 minutes to get the extract clear and colourless. Precaution was taken while adding the hydrogen peroxide as excess of it might oxidise ammonia in the absence of organic matter.

The digested peroxide material was transferred to 100 ml volumetric flasks and the volume was made upto the mark with 2-3 washings using double distilled water. The required amount of aliquot (digested peroxide material) was used to estimate its nitrogen, phosphorus and potassium percentage.

3.11.1.1 Leaf-nitrogen content

The method of Lindner (1944) was followed, wherein 10 ml aliquot of the diluted peroxide-digested material was taken in a 50 ml volumetric flask and the excess of the acid was neutralised by 2 ml of 2.5 N sodium hydroxide solution. 1 ml of 10% sodium silicate solution was added to prevent turbidity and the volume was made upto the mark with double distilled water. 5 ml of this solution was taken in a 10 ml graduated test tube and 0.5 ml of Nessler's reagent was added dropwise, mixing it thoroughly after each drop. Distilled water was used to make the final volume upto 10 ml and the tube was allowed to stand for about 5 minutes for proper colour development. The solution was transferred to a colorimetric tube and the transmittance was noted at 525 nm on a Baush and Lomb " Spectronic-20" colorimeter. A blank was run with each set. A calibration curve was obtained by using known dilutions of a standard ammonium sulphate solution.

3.11.1.2 Leaf-phosphorus content

It was estimated by the method of Fiske and Subba Row (1925). A 5 ml aliquot was taken in a 10 ml graduated test tube. To it, 1 ml of 2.5% molybdic acid was added carefully and then 0.4 ml of 1-amino-2-nepthal-4-sulphonic acid was added. The solution turned blue. The volume was made upto 10 ml with the addition of distilled water. The solution was stirred throughly and allowed to stand for about 5 minutes for proper colour development. The solution was transferred to a colorimetric tube and the transmittance was noted at 620 nm on a Baush and Lomb " Spectronic-20" colorimeter. A blank was run with each set. A standard curve was drawn by using known concentrations of monobasic potassium phosphate solution.

3.11-1.3 Leaf-potassium content

The potassium content of the leaf was estimated using a flame photometer. 1 ml aliquot was appropriately diluted with distilled water. A blank was run side by side which contained only distilled water. Reading was taken using the filter for potassium at 740 nm and compared with a standard curve which was plotted by using known graded concentrations of potassium sulphate solution.

3.12 Grain protein content

Protein in the grain powder was estimated by the method of Lowry *et al*. (1951). 50 mg of dry grain powder was weighed and transferred to a mortar and ground by a pastle with 5 ml of distilled water. The ground material was collected in a centrifuge tube. The tube was centrifuged at 4,000 rpm. The supernatant was collected in a 25 ml volumetric flask using two or three washings with distilled water. The volume was made upto the mark with distilled water and kept for the estimation of soluble protein. The residue was used for the estimation of insoluble protein.

The following reagents were prepared for the estimation:

Reagent A - 2% sodium carbonate in 0.1 N sodium hydroxide in 1:1 ratio.

Reagent B - 0.5% copper sulphate in 1% sodium tartarate in 1:1 ratio.

Reagent C - Alkaline copper sulphate solution obtained by mixing 50 ml of Reagent A with 1 ml of Reagent B.

Reagent D - Carbonate copper sulphate solution obtained by mixing 50 ml of 2% sodium carbonate with 1 ml of Reagent B.

Reagent E - Diluted folin reagent, obtained by diluting the folin reagent to make it 1 N in acid.

3.12.1 Soluble proteins

1 ml of water extract was taken in a 10 ml test tube and 5 ml of Reagent C was added to the extract. The solution

was mixed well and allowed to stand for 10 minutes at room temperature. 0.5 ml of Reagent E was added rapidly with immediate mixing. The solution was left for 30 minutes. A blue coloured solution was obtained and transferred to a colorimetric tube and the optical density read at 660 nm on a Baush and Lomb " Spectronic 20" colorimeter. A blank was run with each sample. Optical density of each sample was compared with standard curve, drawn using known dilutions of egg albumen.

3.12.2 Insoluble proteins

The residue left after extraction of soluble protein was taken and 5 ml of 5% trichloroacetic acid was added to it. The solution was shaken thoroughly and allowed to stand at room temperature. After 30 minutes, the solution was transferred to a centrifuge tube and it was centrifuged for 10 minutes at 4,000 rpm. The supernatant was discarded. To the residue, 5 ml of 1N sodium hydroxide was added and mixed well and left for 30 minutes. The solution was centrifuged and the supernatant was collected in a 25 ml volumetric flask. The residue was washed two to three times with 1N sodium hydroxide solution and washings were collected in the flask. The volume was made upto the mark with 1N sodium hydroxide solution.

1 ml of this sodium hydroxide extract was taken in a 10 ml test tube and 5 ml of Reagent D was added. The solution

was mixed thoroughly and allowed to stand for 10 minutes at room temperature. 0.5 ml Reagent E was added rapidly with immediate mixing. After about 30 minutes, the solution turned blue. The optical density of this solution was read at 660 nm on a Baush and Lomb " Spectronic 20" colorimeter. A blank was run with each sample. The optical density of this solution was compared with standard curve, used for soluble protein.

3.12.3 Total proteins

The total protein content of the grain was obtained by adding the values for the soluble and insoluble protein content.

3.13 Grain carbohydrate content

Soluble and insoluble carbohydrates were extracted according to the method of Yih and Clark (1965) and estimated by the method of Dubois *et al*. (1956). 50 mg of dried grain powder was taken in a centrifuge tube. To it, 5 ml of 80% alcohol was added and heated on a water bath for 10 minutes. The tube was cooled and then centrifuged at 4,000 rpm for 10 minutes. The supernatant was collected in a 25 ml volumetric flask,using two to three washings with 5 ml of 80% alcohol. The volume was made upto the mark. The residue was kept for the estimation of insoluble carbohydrates.

3.13.1 Soluble carbohydrates

1 ml of the alcoholic extract was taken in a 10 ml test tube and dried on a water bath. When the alcohol was completely evaporated, the test tube was taken out from the water bath. After cooling, 2 ml of distilled water was added to the test tube. 1 ml of 5% phenol and 5 ml conc. sulphuric acid was added and mixed. A light orange colour developed. After cooling for 30 minutes, it was transferred to a colorometric tube and the optical density of the solution was read at 490 nm on a Baush and Lomb " Spectronic 20" colorimeter. A blank was run with each sample. The soluble carbohydrates of each sample were obtained by comparing its optical density with a calibration curve plotted by taking known dilutions of a standard solution of chemically pure glucose.

3.13.2 Insoluble carbohydrates

The residues, after extraction of soluble carbohydrates, was used for the estimation of insoluble carbohydrates. 5 ml of 1.5 N sulphuric acid was added to this residue and heated on a water bath for about 2 hours. The tube was then taken out of the water bath and cooled. After cooling, it was transferred to a centrifuge tube and centrifuged at 4,000 rpm for 10 minutes. The extract was collected in a 25 ml volumetric flask. The residue was washed two to three times with distilled water and the washings transferred to volumetric flask and the volume was made upto the mark with distilled water. 1 ml of the solution was taken from the volumetric flask. To it, 1 ml of 5% phenol was added, followed by 5 ml of conc. sulphuric acid. A light orange colour developed. The tube was cooled for 30 minutes and then it was transferred to a colorimetric tube and the optical density of the solution was read at 490 nm on a Baush and Lomb " Spectronic 20" colorimeter. A blank was run with each sample. The insoluble carbohydrate content was calculated by comparing its optical density with a calibration curve, used for soluble carbohydrate.

3.13.3 Total carbohydrates

The values of soluble and insoluble carbohydrates were added to get the total carbohydrate content of the grain.

3.14 Milling and baking

The grains of triticale and wheat were grinded once in the commercial mills and the final percentage of flour of the two crops was recorded as indicated below :

Crop	Initial wt. (kg)	Final wt. (kg)	Bran (%)	Flour(%)
Triticale (Delfin)	10.00	8.00	20.00	80.00
Wheat (HD-2204)	10.00	8.50	15.00	85.00

For the assessment of some of the baking properties the following procedure was adopted:

3.14.1 Preparation of loaf (" Buns")

Loaves were made by using the method of " Remix" baking test (Irvine and McMullan, 1960) with some modifications. There were three samples of flour, triticale flour (100%), wheat flour (100%) and a (1:1) blend of triticale and wheat flour.

1 kg flour of each sample was taken and passed through a 100 mesh sieve (Lorenz et al., 1972). Of this, 0.5 kg of fine flour ("Maida") was taken. 1.25 g of yeast was then added and mixed properly with water and kept for 165 minutes at 30°C (Irvine and Mc Mullan, 1960) for fermentation. To the fermented dough, 150 g sugar was added and the mixture was beat for about 10 minutes. After that, small round balls were made, each containing 100 g of flour, and baked in an oven at a temperature of 220°C for about 25 minutes (Irvine and Mc Mullan, 1960).

3.14.2 Preparation of chapatti

The flour of wheat, triticale and 1:1 blend was taken separately. Water was added and mixed properly by hands and dough was prepared. After that round balls, each containing 50 g flour, were made which were spread in round shape about 20 cm in diameter with the help of plane wooden base and a wooden rolling pin and then baked on a slightly concave iron plate kept over the direct flame of a gas burner.

3.14.3 Quality test

The softness and flavour of the loaf and chapatti were evaluated by two different panels. The panel for evaluating the loaf consisted of 10 untrained university students and the panel for evaluating the chapatti consisted a group of another 10 students. The samples were coded as A, B and C for each sample distinctly marked for proper identification. The panel members were asked to determine the softness of the loaf and chapattis. They were also asked to taste them to decide flavour with the help of the folowing key prepared for this purpose. Three replications of each test were arranged on different days.

Key for panel evaluation of softness and flavour of loaf and chapatti -

Softness		Flavour	
Mushy	1	Good	1
Soft	2	Likable	2
Slightly soft	3	Slightly likable	3
Slightly tough	4	Slightly distasteful....	4
Tough	5	Distasteful	5

3.15 Statistical analysis

All the experimental data were analysed by adopting rigorous "F'' tests in which the error due to replicates was also determined, according to Panse and Sukhatme (1985). When "F'' value was found to be significant at the 5% level of probability, critical difference (C.D.) was calculated. The models of the analysis of variance (ANOVA) are given in Table 5.

Table 5. Models of the analysis of variance (ANOVA)

Experiment 1 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	'F'.
Replication	2			
Treatments (T)	3			
Cultivars (Cv)	4			
T x Cv	12			
Error	38			
Total	59			

Experiment 2 (Factorial randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	'F'
Replication	2			
Treatment (T)	7			
Cultivars (Cv)	1			
T x Cv	7			
Error	30			
Total	47			

Experiment 3 (Simple randomised block design)

Source of variation	D.F.	S.S.	M.S.S.	'F'
Replication	2			
Treatment	3			
Error	6			
Total	11			

CHAPTER 4

EXPERIMENTAL RESULTS

CONTENTS

Page

EXPERIMENTAL RESULTS

4.1 EXPERIMENT 1

The aim of this factorial randomised field experiment was to test the comparative performance of four cultivars of triticale, namely Delfin, Driera, TL-419 and Tigre'S' vis-a-vis wheat check HD-2204 under two levels of basal phosphorus, viz. 45 and 60 kg P_2O_5/ha and a uniform dose of potassium (30 kg K/ha). Whereas 100 kg N/ha was supplied in all 20 treatments at the time of sowing, an additional 50 kg N/ha was top-dressed in half of them at tillering. The response of the various cultivars to two treatments ($N_{100}P_{45}K_{30}$ and $N_{100}P_{60}K_{30}$) only was, therefore, recorded at tillering stage. However, at heading and milky grain stages of growth, there were four treatments, namely, $N_{100}P_{45}K_{30}$, $N_{100}P_{60}K_{30}$, $N_{100+50}P_{45}K_{30}$ and $N_{100+50}P_{60}K_{30}$.

The data regarding growth and yield characteristics as well as leaf -N, -P and -K contents and grain quality (Table 6-28), as affected by the treatments, cultivars and their interactions at tillering, heading and milky grain stages of growth are briefly described below:

4.1.1 Growth characteristics

Shoot length, tiller number, leaf number, fresh weight and dry weight per plant were noted at tillering, heading and milky grain stages of growth. The results are described parameter-wise in the following pages:

4.1.1.1 Shoot length per plant

Table 6 clearly reveals that application of the higher dose of phosphorus (60 kg P_2O_5/ha) produced significantly taller plants than the lower dose (45 kg P_2O_5/ha at all the three stages of growth of the cultivars. Thus, treatment $N_{100}P_{60}K_{30}$ increased shoot length by 1.78%, 7.15% and 11.12% over $N_{100}P_{45}K_{30}$ at tillering, heading and milky grain stage respectively. Similarly, treatment $N_{100+50}P_{60}K_{30}$ gave 2.13% and 11.42% taller plants compared with $N_{100+50}P_{45}K_{30}$ at heading and milky grain stages respectively. It was also noted that plant height increased faster between tillering and heading than between heading and milky grain stage.

In general, shoot length per plant increased in all cultivars of triticale as growth progressed, whereas wheat reached its maximum height at heading stage. Among the four cultivars of triticale, Delfin responded best, giving 21.69%, 17.28% and 35.50% more plant height at tillering, heading and milky grain stage respectively than Tigre 'S', the least responsive cultivar in this regard, except at tillering stage. On the other hand, Delfin was noted to be 17.93%, 23.91% and 50.95% taller than wheat at tillering, heading and milky grain stage respectively.

Table 6. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on shoot length (cm) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Sampling stages: Tillering, Treatments (kg N+P_2O_5/ha)			Heading, Treatments (kg N+P_2O_5/ha)					Milky grain, Treatments (Kg N+P_2O_5/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
Wheat	66.00	66.40	66.20	81.80	89.77	92.30	93.73	89.40	82.55	92.91	87.15	97.72	90.00
Delfin	76.53	79.60	78.07	102.17	110.67	113.23	117.03	110.78	127.35	140.32	127.91	148.34	135.98
Driera	46.57	47.27	46.92	99.30	108.37	112.43	113.93	108.51	106.13	124.44	109.88	127.64	119.02
TL-419	68.07	70.43	69.25	92.07	96.40	98.63	101.20	97.08	97.53	105.43	104.32	111.40	104.67
Tigre'S'	64.53	63.77	64.15	89.37	92.77	97.00	98.67	94.45	95.23	102.30	99.63	104.25	100.35
Mean	64.34	65.49		92.94	99.59	102.72	104.91		101.76	113.08	105.78	117.87	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%	C.D.at 5%	C.D.at 5%
Treatments	0.92	1.00	0.92
Cultivar	1.46	1.12	1.03
Treatment x Cultivar	N.S.	2.25	2.05

N.S. - Non significant

On comparing treatment x cultivar (T x Cv) interaction effects, the combination found to be most effective was $N_{100+50}P_{60}K_{30}$ x Delfin. It increased shoot length by 43.06% and 79.70% at heading and milky grain stage respectively over $N_{100}P_{45}K_{30}$ x wheat, which proved the least effective combination. However, the interaction effect of T x Cv at tillering stage was not significant. Comparing the interaction effect of Delfin with the treatments containing P_{60} and P_{45}, $N_{100}P_{60}K_{30}$ x Delfin produced 8.32% and 10.18% taller plants at heading and milky grain stage respectively than $N_{100}P_{45}K_{30}$x Delfin, while $N_{100+50}P_{60}K_{30}$ x Delfin increased plant height over $N_{100+50}P_{45}K_{30}$ x Delfin by 3.36% and 15.97% respectively at the two stages. It may be pointed out that, in general, all other triticale cultivars also exhibited faster rate of vertical growth with 60 kg P_2O_5/ha at the same level of applied nitrogen (100 or 100+50 kg N/ha) between heading and milky grain stages when the interaction effect was significant. Of course, this positive effect of the higher phosphorus dose on shoot length was more conspicuous in each cultivar in the combinations comprising N_{100+50} than those with N_{100}/ha (Table 6).

4.1.1.2 Tiller number per plant

It is evident from Table 7 that the higher dose of phosphorus (60 kg P_2O_5/ha) produced more tillers than the lower dose (45 kg P_2O_5/ha). Thus, at tillering, heading and milky

Table 7. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on tiller number per plant of four cultivars of triticale and wheat check. (Mean of three replicates)

Cultivars	Sampling stages												
	Tillering			Heading					Milky grain				
	Treatments(kg $N+P_2O_5$/ha)			Treatment (kg $N+P_2O_5$/ha)					Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
Wheat	8.67	9.67	9.17	8.33	9.67	10.33	10.67	9.75	8.67	9.33	11.67	10.67	10.08
Delfin	11.67	14.67	13.17	9.67	14.67	13.33	16.67	13.58	9.67	13.33	12.67	17.33	13.25
Driera	8.67	9.67	9.17	8.67	8.67	10.67	10.67	9.67	8.00	8.67	10.00	10.33	9.25
TL-419	8.00	8.33	8.17	9.33	10.67	11.67	12.33	11.00	9.00	10.33	11.33	11.67	10.58
Tigre'S'	8.33	9.33	8.83	8.33	9.33	10.00	10.33	9.50	8.67	8.67	9.33	9.33	9.00
Mean	9.07	10.33		8.87	10.60	11.20	12.13		8.80	10.07	11.00	11.87	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%	C.D.at 5%	C.D.at 5%
Treatments	0.48	0.44	0.40
Cultivar	0.76	0.49	0.45
Treatment x Cultivar	1.07	0.97	0.91

grain stage, $N_{100}P_{60}K_{30}$ produced 13.89%, 19.50% and 14.43% more tillers than $N_{100}P_{45}K_{30}$. Similarly, $N_{100+50}P_{60}K_{30}$ produced 8.30% and 7.91% more tillers than $N_{100+50}P_{45}K_{30}$ at heading and milky grain stage respectively.

Among the cultivars tested, Delfin proved best irrespective of the stage of growth. Wheat closely followed it at tillering. However, the latter lagged behind Delfin and even TL-419, at heading and milky grain stages.

T x Cv interaction effect on tiller production was significant at all stages. Considering all combinations, Delfin interacted best with $N_{100+50}P_{60}K_{30}$ at each stage. On the other hand, $N_{100}P_{45}K_{30}$ x TL-419 at tillering and $N_{100}P_{45}K_{30}$ x Driera at heading and milky grain stages produced minimum tillers (Table 7).

4.1.1.3 <u>Leaf number per plant</u>

Leaf number was significantly affected by treatments (Table 8). $N_{100}P_{60}K_{30}$, containing the higher dose of basal phosphorus produced 8.53%, 9.13% and 9.09% more leaves at tillering, heading and milky grain stage respectively than $N_{100}P_{45}K_{30}$. On the other hand, $N_{100+50}P_{60}K_{30}$ was 11.78% and 7.41% better in its effect at heading and milky grain stage respectively than $N_{100+50}P_{45}K_{30}$.

Table 8. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on leaf number per plant of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Sampling stages												
	Tillering			Heading					Milky grain				
	Treatments(kg $N+P_2O_5$/ha)			Treatments (kg $N+P_2O_5$/ha)					Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
Wheat	39.33	47.33	43.33	36.33	41.00	40.33	45.00	40.67	38.33	39.33	43.67	45.33	41.67
Delfin	61.33	67.33	64.33	61.67	64.67	68.67	73.67	67.17	61.67	65.67	69.33	70.33	66.75
Driera	39.33	38.67	39.00	32.35	34.67	34.33	40.00	35.33	30.00	33.33	31.67	37.67	33.17
TL-419	46.00	50.00	48.00	44.00	50.67	50.33	55.33	50.08	40.00	47.33	46.33	51.67	45.33
Tigre'S'	28.33	29.33	28.83	26.00	27.67	29.67	35.67	29.75	24.67	26.67	29.67	32.00	28.25
Mean	42.87	46.53		40.07	43.73	44.67	49.93		38.93	42.47	44.13	47.40	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%	C.D.at 5%	C.D.at 5%
Treatments	1.44	1.32	1.35
Cultivar	2.27	1.48	1.51
Treatment x Cultivar	3.21	N.S.	3.00

N.S. - Non significant

Delfin proved most prolific in leaf production and Tigre'S', the least, at all the three stages. Wheat occupied a middle position. Thus, leaf production in Delfin was 48.46%, 65.16% and 60.18% higher than in wheat and tillering, heading and milky grain stage respectively.

The T x Cv effect on leaf number was significant at tillering and milky grain stages only. In general, Delfin produced more leaves with both phosphorus levels compared with the interaction of other cultivars with the respective phosphorus level at both stages. Top-dressing with nitrogen (N_{100+50}) augmented the effect of phosphorus more than basal application (N_{100}) alone (Table 8).

4.1.1.4 Fresh weight per plant

Like the other parameters considered above, this parameter was also significantly affected by the treatments (Table 9). The higher dose of phosphorus (P_{60}) resulted in 11.59%, 14.64% and 10.85% higher fresh weight at tillering, heading and milky grain stage respectively than $N_{100}P_{45}K_{30}$. Similarly, $N_{100+50}P_{60}K_{30}$ produced 9.50% and 9.46% more fresh matter than $N_{100+50}P_{45}K_{30}$ at heading and milky grain stage respectively.

Cultivar differences were significant and clear-cut at all stages. Delfin proved the best performing cultivar for fresh weight and wheat occupied a middle position.

.ble 9. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on fresh weight per plant (g) of four cultivars of triticale and a wheat check. (Mean of three replicates)

.ltivars	Sampling stages												
	Tillering			Heading					Milky grain				
	Treatments(kg $N+P_2O_5$/ha)			Treatments (kg $N+P_2O_5$/ha)					Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
ıeat	20.40	25.80	23.10	41.53	51.63	59.57	62.43	53.79	83.30	94.21	103.70	114.36	98.92
·lfin	42.30	46.57	44.43	90.73	101.33	102.77	115.17	102.50	133.05	147.44	158.60	169.06	152.04
·iera	21.93	23.43	22.68	40.83	46.87	51.63	51.60	47.73	69.35	76,84	79.80	90.84	79.21
,-419	33.20	36.50	34.85	82.90	91.47	92.70	100.97	92.01	109.84	122.60	125.50	137.25	123.80
gre'S'	19.70	21.00	20.45	45.27	54.03	50.90	61.33	52.88	78.22	84.06	87.59	96.24	86.53
an	27.51	30.70		60.25	69.07	71.51	78.30		94.75	105.03	111.05	121.55	

B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%	C.D. at 5%	C.D.at 5%
·eatments	1.05	0.88	0.44
.ltivar	1.66	0.99	0.50
·eatment x Cultivar	N.S.	1.98	1.00

S.- Non significant

The interaction effect (T x Cv) was significant at heading and milky grain stages only. The combination $N_{100+50}P_{60}K_{30}$ x Delfin gave the highest fresh weight at both stages. The treatment $N_{100+50}P_{60}K_{30}$ interacted better with the remaining cultivars also compared with their respective interactions with $N_{100}P_{45}K_{30}$ and even $N_{100}P_{60}K_{30}$. Incidently, $N_{100}P_{45}K_{30}$ x wheat/Driera/Tigre'S' were among the combinations that resulted in the lowest fresh weight at each of the two stages. Even when the nutrient dose was increased to $N_{100}P_{60}K_{30}$ or $N_{100+50}P_{45}K_{30}$, these three cultivars did not interact well enough to give fresh weight anywhere near the interaction effect of either of these treatments with Delfin, what to say of the effect of the best combination ($N_{100+50}P_{60}K_{30}$x Delfin) noted above (Table 9).

4.1.1.5 Dry weight per plant

This most important among the growth characteristics was significantly affected at all stages (Table 10).

The treatment $N_{100}P_{60}K_{30}$, containing the higher dose of phosphorus, gave 18.29%, 13.86% and 16.17% higher dry weight than $N_{100}P_{45}K_{30}$ at tillering, heading and milky grain stage respectively. The difference between the effect of $N_{100+50}P_{60}K_{30}$ and $N_{100+50}P_{45}K_{30}$ regarding dry matter production was 11.77% and 7.98% at heading and milky grain stage respectively. Interestingly at milky grain stage, $N_{100}P_{60}K_{30}$

able 10. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on dry weight per plant (g) of four cultivars of triticale and a wheat check. (Mean of three replicates)

ultivars	Sampling stages												
	Tillering			Heading					Milky grain				
	Treatments (kg $N+P_2O_5$/ha)			Treatments (kg $N+P_2O_5$/ha)					Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
heat	5.27	7.17	6.22	13.37	16.50	15.63	19.40	16.23	21.37	26.21	25.54	30.83	25.99
elfin	6.60	9.37	7.98	30.67	33.50	32.23	39.53	33.98	35.18	39.73	42.29	43.67	40.22
riera	5.97	6.20	6.08	13.40	15.43	16.37	17.43	15.66	20.26	22.50	21.28	22.84	21.72
L-419	7.07	7.80	7.43	25.63	28.33	31.30	32.30	29.32	30.12	35.41	32.56	34.10	33.05
lgre'S'	5.43	5.37	5.40	14.70	17.53	20.30	20.47	18.25	21.12	24.88	22.40	24.11	23.13
ean	6.07	7.18		19.55	22.26	23.11	25.83		25.61	29.75	28.8[illegible]	31.11	

.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
reatments	0.25	0.29	0.28
ltivar	0.40	0.32	0.32
reatment x Cultivar	0.57	0.64	0.64

produced slightly more dry matter than $N_{100+50}P_{45}K_{30}$.

Delfin, followed by TL-419, proved most efficient for dry matter production at each stage, with wheat check occupying a middle position.

Regarding the T x Cv interaction effect, $N_{100+50}P_{60}K_{30}$x Delfin out yielded all other combinations with respect to dry weight at each of the three stages. In fact, Delfin interacted much better than all other cultivars even with the lower doses of fertiliser nitrogen (N_{100}) and phosphorus (P_{45}) at each stage. The lowest dry matter was recorded among combinations consisting of $N_{100}P_{45}K_{30}$ and wheat, Driera or Tigre'S', (Table 10) as was noted for fresh weight (Table 9).

4.1.2 <u>Leaf analysis</u>

Leaves were analysed for studying the effect of the two doses of phosphorus applied under the two regimes of nitrogen. Of the attributes investigated, nitrate reductase activity was assayed in fresh leaves and leaf -N, -P and -K contents in dried leaf powder at tillering, heading and milky grain stages. The data have been summarised in Tables 11-14 and are briefly considered below:

4.1.2.1 <u>Leaf-nitrate reductase activity</u>

Leaf NRA was affected significantly by treatments, cultivar and T x Cv interaction at all stages.

Higher phosphorus dose increased leaf NRA at both regimes of nitrogen (N_{100} and N_{100+50}). Thus, $N_{100}P_{60}K_{30}$ increased it over $N_{100}P_{45}K_{30}$ by 6.06%, 4.87% and 11.76% at tillering, heading and milky grain stage respectively, while $N_{100+50}P_{60}K_{30}$ had an edge over $N_{100+50}P_{45}K_{30}$ of 5.55% and 7.69% at heading and milky grain stage respectively (Table 11).

Cultivars differed critically in their leaf NRA at each of the three stages, with Delfin showing the highest activity and Tigre'S', the lowest. Wheat had intermediate leaf NRA activity.

Treatment x cultivar interaction effect was also significant at all the three stages. At both phosphorus levels, Delfin showed the highest and Tigre'S', the lowest NRA among comparable combinations.

4.1.2.2 Leaf-nitrogen content

The effect of treatment, cultivar and T x Cv interaction on the concentration of nitrogen in the leaves was significant at all the three stages (Table 12).

Of the two treatments, viz. $N_{100}P_{45}K_{30}$ and $N_{100}P_{60}K_{30}$, the latter resulted in 4.95%, 7.10% and 1.03% higher leaf nitrogen content at tillering, heading and milky grain stage respectively. Considering the additional effect of top-dressing with 50 kg N/ha, $N_{100+50}P_{60}K_{30}$ increased leaf able 11. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on leaf-NRA(μ mole NO_2^-/g/h) of four cultivars of triticale and a wheat check. (Mean of three replicates)

ultivars	Sampling stages												
	Tillering			Heading					Milky grain				
	Treatments(kg N+P_2O_5/ha)			Treatments (kg N+P_2O_5/ha)					Treatments (kg N+P_2O_5/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
heat	0.33	0.33	0.33	0.40	0.42	0.52	0.53	0.47	0.31	0.36	0.36	0.41	0.36
elfin	0.40	0.45	0.43	0.48	0.51	0.72	0.75	0.62	0.45	0.49	0.51	0.55	0.50
riera	0.28	0.31	0.29	0.40	0.40	0.51	0.51	0.46	0.30	0.32	0.34	0.34	0.33
L-419	0.38	0.38	0.38	0.40	0.47	0.61	0.64	0.53	0.37	0.40	0.44	0.45	0.41
igre'S'	0.25	0.26	0.26	0.34	0.33	0.34	0.43	0.36	0.25	0.31	0.32	0.33	0.30
ean	0.33	0.35		0.41	0.43	0.54	0.57		0.34	0.38	0.39	0.42	

.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%	C.D.at 5%	C.D.at 5%
reatments	0.01	0.01	0.01
ultivar	0.02	0.01	0.01
reatment x Cultivar	0.02	0.03	0.01

able 12. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on leaf-nitrogen content (%) of four cultivars of triticale and a wheat check. (Mean of three replicates)

ıltivars	Sampling stages												
	Tillering			Heading					Milky grain				
	Treatments(kg $N+P_2O_5$/ha)			Treatments (kg $N+P_2O_5$/ha)					Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
neat	5.04	5.41	5.22	4.07	4.41	5.84	6.02	5.09	3.58	3.85	4.54	5.09	4.29
elfin	6.12	6.48	6.30	4.99	5.30	6.93	7.15	6.09	4.41	4.41	5.75	6.46	5.25
riera	4.81	5.04	4.92	3.79	4.27	5.28	5.46	4.70	3.74	3.70	4.30	4.83	4.14
L-419	5.33	5.62	5.47	4.31	4.52	5.98	6.25	5.26	3.94	4.05	4.71	5.25	4.48
igre'S'	4.96	5.04	5.00	3.98	4.11	5.10	5.31	4.62	3.58	3.58	4.41	4.70	4.06
ean	5.25	5.51		4.22	4.52	5.83	6.03		3.87	3.91	4.74	5.26	

.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D. at 5%	C.D. at 5%	C.D. at 5%
reatments	0.05	0.04	0.03
ultivar	0.09	0.05	0.04
reatment x Cultivar	0.15	0.10	0.08

nitrogen content over $N_{100+50}P_{45}K_{30}$ by 3.43% and 10.97% at heading and milky grain stage respectively.

Among the cultivars, Delfin possessed the highest and Tigre'S', the lowest leaf nitrogen content at each stage, with wheat check occupying a middle position. Almost all cultivars differed critically with each other in this respect at each stage.

T x Cv interaction effect was maximum for each cultivar in the treatment $N_{100+50}P_{60}K_{30}$ at the heading stage, Delfin giving the highest value. $N_{100}P_{45}K_{30}$ x Tigre'S' gave the lowest leaf nitrogen content at milky grain stage. In general, individual cultivars interacted better with the higher phosphorus level and resulted in higher leaf nitrogen content at each growth stage. However, the difference was not marked between $N_{100}P_{60}K_{30}$ and $N_{100}P_{45}K_{30}$ for each cultivar at the milky grain stage (Table 12).

4.1.2.3 Leaf-phosphorus content

The effect of treatment and treatment x cultivar interaction was significant at heading and milky grain stages, whereas cultivars differed significantly with each other in their leaf phosphorus content at all three stages. At heading and milky grain stage, $N_{100}P_{60}K_{30}$ resulted in 10.34% and 14.29% higher leaf phosphorus concentration than $N_{100}P_{45}K_{30}$, while $N_{100+50}P_{60}K_{30}$ bettered $N_{100+50}P_{45}K_{30}$ by 27.59% and 15.63% respectively.

Delfin possessed the highest leaf phosphorus content and Tigre'S', the lowest at each stage. Wheat check was intermediate in this regard.

At both heading and milky grain stage, the higher dose of applied phosphorus (P_{60}), in conjunction both with N_{100} and N_{100+50}, resulted in higher leaf phosphorus concentration than P_{45}, the lower basal phosphorus level, while interacting with individual cultivars. The most effective interaction in this respect was $N_{100+50}P_{60}K_{30}$ x Delfin at milky grain stage (Table 13).

4.1.2.4 Leaf-potassium content

As is evident from Table 14, the effect of treatment, cultivar and treatment x cultivar interaction on the potassium concentration of leaf was significant at all stages.

Treatment $N_{100}P_{60}K_{30}$ resulted in 5.96%, 2.59% and 4.49% higher leaf potassium content than $N_{100}P_{45}K_{30}$ at tillering, heading and milky grain stage respectively. Treatment $N_{100+50}P_{60}K_{30}$ resulted in 5.14% higher value than $N_{100+50}P_{45}K_{30}$ at heading stage while at milky grain stage the values for the two treatments were at par.

By and large, cultivars differed critically from each other in their leaf potassium concentration at each stage. Delfin consistently exhibited the highest content and Tigre'S', the lowest.

Table 13. **Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on leaf-phosphorus content (%) of four cultivars of triticale and a wheat check. (Mean of three replicates)**

Cultivars	Sampling stages												
	Tillering			Heading					Milky grain				
	Treatments(kg $N+P_2O_5$/ha)			Treatments (kg $N+P_2O_5$/ha)					Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
Wheat	0.30	0.30	0.30	0.27	0.31	0.31	0.35	0.31	0.26	0.31	0.29	0.35	0.31
Delfin	0.34	0.37	0.36	0.35	0.40	0.34	0.36	0.39	0.32	0.36	0.42	0.45	0.39
Driera	0.27	0.27	0.27	0.27	0.29	0.27	0.33	0.29	0.25	0.31	0.28	0.32	0.29
TL-419	0.30	0.30	0.30	0.31	0.33	0.28	0.39	0.33	0.30	0.34	0.37	0.39	0.35
Tigre'S'	0.25	0.25	0.25	0.25	0.27	0.25	0.32	0.27	0.25	0.27	0.26	0.31	0.28
Mean	0.30	0.29		0.29	0.32	0.29	0.37		0.28	0.32	0.32	0.37	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%	C.D.at 5%	C.D.at 5%
Treatments	N.S.	0.01	0.01
Cultivar	0.03	0.01	0.01
Treatment x Cultivar	N.S.	0.01	0.01

N.S. - Non significant

Table 14. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on leaf-potassium content (%) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Sampling stages											
	Tillering			Heading					Milky grain				
	Treatments(kg $N+P_2O_5$/ha)			Treatments (kg $N+P_2O_5$/ha)					Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	Mean	100+45	100+60	150+45	150+60	Mean	100+45	100+60	150+45	150+60	Mean
Wheat	4.70	5.18	4.94	4.19	4.32	5.52	5.69	4.90	4.22	4.52	5.03	5.20	4.74
Delfin	5.81	6.13	5.97	4.80	4.84	6.69	6.99	5.83	5.11	5.42	5.61	5.88	5.51
Driera	4.61	4.82	4.71	4.02	4.13	5.01	5.21	4.59	4.42	4.30	4.64	4.74	4.53
TL-419	4.84	5.10	4.97	4.09	4.43	5.29	5.76	4.89	4.52	4.90	5.82	5.31	5.14
Tigre'S'	4.36	4.52	4.44	4.09	4.01	4.70	4.95	4.43	3.98	4.10	4.16	4.25	4.12
Mean	4.86	5.15		4.24	4.35	5.44	5.72		4.45	4.65	5.05	5.08	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%	C.D.at 5%	C.D.at 5%
Treatments	0.03	0.04	0.04
Cultivar	0.05	0.05	0.05
Treatment x Cultivar	0.09	0.10	0.10

Highest leaf potassium content was recorded in the combination $N_{100+50}P_{60}K_{30}$ x Delfin at heading stage and the lowest, in $N_{100}P_{45}K_{30}$ x Tigre'S' at the milky grain stage. Treatment x wheat interaction effects were intermediate between the two extremes at each stage. In general, raising the basal phosphorus dose from 45 kg to 60 kg P_2O_5/ha resulted in higher leaf potassium content in each cultivar at the three stages (Table 14).

4.1.3 Yield characteristics

Tables 15-22 reveal that the effect of treatments, cultivars and treatment x cultivar interaction was significant on all yield attributes. These data are considered parameter-wise below:

4.1.3.1 Ear number per plant

The effect of higher basal phosphorus dose (P_{60}) was better than that of the lower dose (P_{45}) at both nitrogen regimes. Thus, $N_{100}P_{60}K_{30}$ produced 19.07% more ears than $N_{100}P_{45}K_{30}$. Similarly, $N_{100+50}P_{60}K_{30}$ bettered $N_{100+50}P_{45}K_{30}$ in ear production by 8.11%.

Among the cultivars, Delfin produced maximum ears and Driera and Tigre'S', the minimum. Wheat occupied the middle position between these extremes.

Regarding the T x Cv interaction effects, $N_{100+50}P_{60}K_{30}$ x Delfin produced maximum ears per plant. $N_{100}P_{45}K_{30}$ x Tigre'S' or wheat as well as $N_{100}P_{45}K_{30}$ x Driera had the poorest effect on this characteristic and were at par with each other (Table 15). Incidently, this characteristic is a measure of production of fertile tillers.

4.1.3.2 Ear weight per plant

Table 16 clearly reveals that the higher dose of basal phosphorus was responsible for enhancing the weight of the ears produced by each plant at both regimes of nitrogen. Thus, $N_{100}P_{60}K_{30}$ bettered $N_{100}P_{45}K_{30}$ by 16.83% while $N_{100+50}P_{60}K_{30}$ increased ear weight by 38.68% over $N_{100+50}P_{45}K_{30}$.

The cultivars were critically different from each other in this respect. Delfin gave the maximum ear weight per plant and wheat, the minimum.

Whereas $N_{100+50}P_{60}K_{30}$ x Delfin gave the highest value for this characteristic and $N_{100}P_{45}K_{30}$ x wheat, the lowest, each treatment x cultivar interaction involving P_{60} was found more effective than that with P_{45} for the respective cultivar (Table 16).

4.1.3.3 Length per ear

It is evident from Table 17 that increasing the basal phosphorus dose from 45 kg to 60 kg P_2O_5/ha resulted in

Table 15. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on ear number per plant of four cultivars of triticale and wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	8.13	9.33	9.67	10.11	9.31
Delfin	9.33	14.11	13.33	16.33	13.27
Driera	7.91	8.11	9.67	9.67	8.84
TL-419	8.91	9.33	10.67	11.11	10.00
Tigre'S'	7.67	9.11	9.67	10.11	9.14
Mean	8.39	9.99	10.60	11.46	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D. at 5%
Treatments	0.21
Cultivar	0.33
Treatment x Cultivar	0.55

Table 16. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on ear weight per plant (g) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	19.88	24.14	22.72	37.48	26.06
Delfin	43.08	51.13	48.13	72.66	53.75
Driera	33.99	38.06	40.19	52.77	41.25
TL-419	34.48	41.65	41.77	56.31	43.55
Tigre'S'	27.14	30.32	35.66	42.12	33.81
Mean	31.72	37.06	37.69	52.27	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.55
Cultivar	0.61
Treatment x Cultivar	1.22

Table 17. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on length per ear (cm) of four cultivars of triticale and wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	14.21	15.02	14.66	14.93	14.71
Delfin	20.55	24.23	22.12	24.98	22.97
Driera	17.27	18.65	19.87	20.15	18.98
TL-419	14.23	16.23	16.61	17.34	16.10
Tigre'S'	15.02	16.49	17.02	17.28	16.45
Mean	16.25	18.13	18.06	18.94	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D. at 5%
Treatments	0.17
Cultivar	0.19
Treatment x Cultivar	0.38

longer ears both at 100 and 100+50 kg N/ha level. Thus, $N_{100}P_{60}K_{30}$ produced 11.56% longer ears than $N_{100}P_{45}K_{30}$. Similarly, application of $N_{100+50}P_{60}K_{30}$ resulted in an increase of 4.87% in ear length than that of $N_{100+50}P_{45}K_{30}$. Interestingly, the effect of $N_{100}P_{60}K_{30}$ was at par with that of $N_{100+50}P_{45}K_{30}$ with respect to ear length.

Each cultivar had critically different ear length than the other, with Delfin at the top and wheat check at the bottom of the ladder.

Treatment x cultivar interaction effect was most pronounced in $N_{100+50}P_{60}K_{30}$ x Delfin and least, in $N_{100}P_{45}K_{30}$ x wheat (and TL-419). The treatments containing P_{60} interacted better with each cultivar than those containing P_{45} both at N_{100} and N_{100+50} level (Table 17).

4.1.3.4 <u>Spikelet number per ear</u>

Perusal of Table 18 reveals that $N_{100}P_{60}K_{30}$ and $N_{100+50}P_{60}K_{30}$ (comprising the higher dose of basal phosphorus) produced 12.02% and 9.40% more spikelets per ear than did $N_{100}P_{45}K_{30}$ and $N_{100+50}P_{45}K_{30}$ (containing the lower basal dose of phosphorus) respectively.

Spikelet production by each cultivar was critically different from the other. Delfin proved to be the most prolific in this regard and wheat check, the least productive.

Table 18. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on spikelet number per ear of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	19.67	21.33	22.33	23.67	21.75
Delfin	31.67	36.33	33.00	40.00	35.25
Driera	27.33	31.00	29.67	33.00	30.25
TL-419	22.67	24.67	26.67	26.33	25.08
Tigre'S'	26.33	29.67	29.67	31.67	29.33
Mean	25.53	28.60	28.27	30.93	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D. at 5%
Treatments	0.60
Cultivar	0.67
Treatment x Cultivar	1.35

Delfin interacted best with the treatments and wheat, the least as far as spikelet production was concerned. Each cultivar interacted better with the treatment containing P_{60} than with that containing P_{45}. However, this did not apply to $N_{100+50}P_{45}K_{30}$ and $N_{100+50}P_{60}K_{30}$ for wheat and TL-419 (Table 18).

4.1.3.5 Grain number per ear

Higher phosphorus dose, particularly with supplemental top dressing of nitrogen, increased significantly the number of grains formed in each ear. This reflects the involvement of phosphorus in promoting tiller fertility. Thus, $N_{100}P_{60}K_{30}$ produced 8.73% and $N_{100+50}P_{60}K_{30}$, 14.68% more grain per ear than did $N_{100}P_{45}K_{30}$ and $N_{100+50}P_{45}K_{30}$ respectively (Table 19).

Among the cultivars, Delfin produced maximum grain; but the poorest performer in this respect was TL-419 and not wheat check.

The number of grains produced per ear was highest in the combination $N_{100+50}P_{60}K_{30}$ x Delfin and was minimum in $N_{100}P_{45}K_{30}$ x TL-419 (and wheat and Tigre'S'). For each individual cultivar, the interaction effect at P_{60} was superior to that at P_{45} at N_{100} as well as N_{100+50} level.

Table 19. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on grain number per ear of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	56.67	61.67	63.33	74.67	64.08
Delfin	66.67	74.00	68.00	85.33	73.50
Driera	61.67	66.33	64.33	72.66	66.25
TL-419	55.33	59.33	61.67	64.67	60.25
Tigre'S'	57.33	62.33	62.67	69.67	63.00
Mean	59.53	64.73	64.00	73.40	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	1.16
Cultivar	1.30
Treatment x Cultivar	2.60

4.1.3.6 1,000 grain weight

Higher phosphorus conspicuously increased 1,000 grain weight (Table 20). Thus, treatment $N_{100}P_{60}K_{30}$ produced 7.85% heavier grain than $N_{100}P_{45}K_{30}$. Similarly, $N_{100+50}P_{60}K_{30}$ proved 11.79% superior to $N_{100+50}P_{45}K_{30}$ in 1,000 grain weight.

Among the cultivar, heaviest grains were produced by Delfin and the lightest, by wheat check.

Comparing the T x Cv interactions, Table 20 reveals that each cultivar produced heavier grains while interacting with the treatments containing P_{60} (at basal 100 as well as 100+50 kg N/ha level of applied nitrogen). The best combination was $N_{100+50}P_{60}K_{30}$ x Delfin and the least effective, $N_{100}P_{45}K_{30}$ x wheat.

4.1.3.7 Grain yield

This most important yield characteristic showed the same general pattern at the growth and yield parameters considered above. Thus, $N_{100}P_{60}K_{30}$ out yielded $N_{100}P_{45}K_{30}$ by 5.80% and $N_{100+50}P_{60}K_{30}$ proved 8.46% more efficacious in grain production than $N_{100+50}P_{45}K_{30}$, revealing clearly the involvement of phosphorus in this morphophysiological activity (Table 21).

Delfin out yielded all other cultivars in grain yield and produced 10.89% more grain than the wheat check that was

Table 20. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on 1,000 grain weight (g) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	43.32	46.40	47.28	50.38	46.85
Delfin	48.22	52.89	52.71	60.02	53.33
Driera	44.17	47.33	46.43	52.59	47.63
TL-419	45.26	49.58	47.37	54.20	49.10
Tigre'S'	44.31	47.32	46.64	51.61	47.47
Mean	45.06	48.60	48.09	53.76	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.11
Cultivar	0.12
Treatment x Cultivar	0.24

Table 21. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on grain yield (q/ha) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	42.53	43.64	46.92	50.76	45.97
Delfin	47.29	50.57	51.43	54.65	50.98
Driera	39.55	40.95	42.15	43.35	41.50
TL-419	43.03	45.81	44.05	51.48	45.98
Tigre'S'	38.44	42.11	41.61	45.48	41.91
Mean	42.17	44.62	45.23	49.06	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.50
Cultivar	0.56
Treatment x Cultivar	1.12

equalled by the indigenously produced triticale cultivar TL-419. The other two cultivars (Driera and Tigre'S' that were at par) were a poor third in grain production.

Table 21 reveals that at N_{100}(as well as N_{100+50}) level, P_{60} interacted better with individual cultivar than P_{45}. Considering all combinations, $N_{100+50}P_{60}K_{30}$ x Delfin proved the most prolific for grain production and $N_{100}P_{45}K_{30}$ x Tigre'S', the least productive.

4.1.3.8 Straw yield

Table 22 clearly shows that the higher dose of basal phosphorus was more effective in straw production than the lower dose. Thus, $N_{100}P_{60}K_{30}$ produced 3.15% and $N_{100+50}P_{60}K_{30}$, 9.34% more straw than $N_{100}P_{45}K_{30}$ and $N_{100+50}P_{45}K_{30}$ respectively.

Delfin out yielded the other cultivars in straw production also. The performance of each cultivar was critically different from the others. Tigre'S' proved the poorest straw producer, with wheat check occupying an intermediate position.

The treatment x cultivar interaction effect on straw yield was more clear-cut at the higner nitrogen regime. $N_{100+50}P_{60}K_{30}$ x Delfin produced more straw than all other combinations and $N_{100}P_{45}K_{30}$ x Tigre'S' as well as $N_{100+50}P_{45}K_{30}$ x Tigre'S' (being at par) proved the poorest straw producer.

Table 22. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on straw yield (q/ha) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	119.17	120.27	125.38	130.54	123.84
Delfin	131.50	134.89	131.92	145.42	135.93
Driera	117.06	118.95	116.50	128.66	120.29
TL-419	121.43	129.05	126.31	141.59	129.59
Tigre'S'	101.41	106.06	103.89	114.23	106.40
Mean	118.11	121.84	120.80	132.09	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	1.10
Cultivar	1.23
Treatment x Cultivar	2.46

4.1.4. Grain analysis

The grain was analysed chemically for its protein and carbohydrate contents and their fractions. The effects of treatments, cultivars and T x Cv interaction were found to be significant (Tables 23-28). The salient points of the data for each component are briefly considered below:

4.1.4.1 Soluble protein content

The grains became richer in soluble protein as a result of application of higher dose of phosphorus (P_{60}) compared with P_{45}(Table 23). The treatments $N_{100}P_{60}K_{30}$ and $N_{100+50}P_{60}K_{30}$ gave 11.51% and 8.15% higher soluble protein than $N_{100}P_{45}K_{30}$ and $N_{100+50}P_{45}K_{30}$ respectively.

All four cultivars of triticale possessed higher soluble grain protein than the wheat check. Delfin, the best performer in this regard, possessed 23.93% more soluble protein than wheat.

The combinations $N_{100}P_{60}K_{30}$ and $N_{100+50}P_{60}K_{30}$ x Delfin (being at par) gave the highest value and $N_{100}P_{45}K_{30}$ x wheat the lowest value for soluble grain protein (Table 23).

4.1.4.2 Insoluble protein content

The effect of the treatments on insoluble protein of the grain (Table 24) was similar to that on the soluble fraction. Thus, $N_{100}P_{60}K_{30}$ improved this component over

Table 23. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on soluble grain protein content (%) for four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	4.45	5.20	4.75	5.17	4.89
Delfin	5.70	6.44	5.72	6.39	6.06
Driera	4.70	5.29	5.14	5.36	5.13
TL-419	5.11	5.58	5.26	5.75	5.43
Tigre'S'	4.77	5.11	4.89	5.18	4.99
Mean	4.95	5.52	5.15	5.57	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.06
Cultivar	0.07
Treatment x Cultivar	0.13

Table 24. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on insoluble grain protein content (%) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	6.89	7.67	7.12	7.84	7.38
Delfin	8.93	9.53	9.35	9.62	9.36
Driera	7.17	7.83	7.36	7.91	7.57
TL-419	7.64	8.51	7.86	8.48	8.12
Tigre'S'	7.17	7.96	7.56	8.14	7.71
Mean	7.56	8.30	7.85	8.40	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.02
Cultivar	0.03
Treatment x Cultivar	0.05

$N_{100+50}P_{45}K_{30}$ by 9.78% and $N_{100+50}P_{60}K_{30}$, over $N_{100+50}P_{45}K_{30}$ by 7.00%.

Cultivar differences also showed the same pattern as in the case of soluble grain protein, all triticale cultivars possessing more insoluble protein than the wheat check. Delfin, being the best performer in this regard gave 26.83% higher value than wheat.

Each treatment interacted better with Delfin than with the remaining cultivars. Among the various combinations $N_{100+50}P_{60}K_{30}$ x **Delfin resulted in the highest insoluble grain** protein and $N_{100}P_{45}K_{30}$ x **wheat** gave the lowest value for this parameter (Table 24).

4.1.4.3 <u>**Total protein content**</u>

It is evident from Table 25 that the higher dose of phosphorus (P_{60}) increased **total** protein by 10.47% and 7.46% over P_{45} at N_{100} and N_{100+50} respectively. Among the four treatments, $N_{100+50}P_{60}K_{30}$ proved best for this important grain quality parameter.

Delfin responded best for total protein content. All triticale cultivars gave higher protein content compared with the wheat check.

The combination $N_{100}P_{60}K_{30}$ x Delfin and $N_{100+50}P_{60}K_{30}$ x Delfin produced the highest concentration of total grain

Table 25. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on total grain protein content (%) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg N+P_2O_5/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	11.34	12.87	11.87	13.01	12.27
Delfin	14.63	15.97	15.07	16.01	15.42
Driera	11.87	13.12	12.50	13.27	12.70
TL-419	12.75	14.09	13.12	14.23	13.55
Tigre'S'	11.94	13.07	12.45	13.32	12.70
Mean	12.51	13.82	13.00	13.97	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.08
Cultivar	0.10
Treatment x Cultivar	0.18

protein but were at par in their effect. The lowest value was recorded in $N_{100}P_{45}K_{30}$ x wheat (Table 25).

4.1.4.4 Soluble carbohydrate content

Table 26 shows that the higher dose of applied phosphorus increased soluble grain carbohydrate content irrespective of the nitrogen regime. Thus, $N_{100}P_{60}K_{30}$ gave 8.31% and $N_{100+50}P_{60}K_{30}$, 10.69% more soluble carbohydrate than $N_{100}P_{45}K_{30}$ and $N_{100+50}P_{45}K_{30}$ respectively.

Delfin possessed the highest content of soluble grain carbohydrate and TL-419 and Tigre'S' (being at par), the lowest. The wheat check occupied an intermediate position in this regard.

Among the various combinations, the effect of $N_{100+50}P_{60}K_{30}$ x Delfin, followed by that of $N_{100+50}P_{60}K_{30}$ x Driera, was the best and that of $N_{100}P_{45}K_{30}$ x wheat, the poorest (Table 26).

4.1.4.5 Insoluble carbohydrate content

This fraction was also enhanced by the higher dose of applied phosphorus, but to a lesser degree (Table 27). Thus, $N_{100}P_{60}K_{30}$ gave 2.40% higher value than $N_{100}P_{45}K_{30}$. Similarly, 1.85% higher insoluble grain carbohydrate was the result of application of $N_{100+50}P_{60}K_{30}$ compared with that of $N_{100+50}P_{45}K_{30}$.

Table 26. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on soluble grain carbohydrate content (%) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	5.32	5.72	5.27	5.92	5.56
Delfin	5.71	6.33	5.82	6.61	6.12
Driera	5.51	5.93	5.61	6.14	5.80
TL-419	5.06	5.36	4.92	5.39	5.18
Tigre'S'	4.84	5.31	5.03	5.44	5.16
Mean	5.29	5.73	5.33	5.90	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.02
Cultivar	0.03
Treatment x Cultivar	0.06

Table 27. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on insoluble grain carbohydrate content (%) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg N+P_2O_5/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	71.00	72.06	81.86	72.16	71.77
Delfin	71.83	72.87	72.15	72.98	72.46
Driera	69.18	71.14	70.85	72.74	70.98
TL-419	67.14	69.71	68.92	70.56	69.08
Tigre'S'	68.15	69.84	68.85	70.76	69.40
Mean	69.46	71.13	70.53	71.84	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.18
Cultivar	0.20
Treatment x Cultivar	0.40

The pattern for cultivar performance was different for this fraction. The wheat check was inferior only to Delfin with regard to insoluble grain carbohydrate content, other cultivars giving lower galues.

Among the T x Cv interaction effects, $N_{100+50}P_{60}K_{30}$ x Delfin, $N_{100}P_{60}K_{30}$ x Delfin and $N_{100+50}P_{60}K_{30}$ x Driera (being at par) gave the highest values for insoluble grain carbohydrate content and $N_{100}P_{45}K_{30}$ x TL-419 the lowest (Table 27).

4.1.4.6 <u>Total carbohydrate content</u>

A perusal of Table 28 reveals that appllication of the higher dose of phosphorus (60 kg P_2O_5/ha) was better for total carbohydrate content than the lower dose (45 kg P_2O_5/ha). Thus, treatment $N_{100}P_{60}K_{30}$ increased total carbohydrate content by 2.82% over $N_{100}P_{45}K_{30}$. Similarly, treatment $N_{100+50}P_{60}K_{30}$ gave 2.47% higher carbohydrate content compared with $N_{100+50}P_{45}K_{30}$.

Delfin gave the highest total carbohydrate content and TL-419, the lowest. The wheat check stood at number two in cultivar-wise sequence of total grain carbohydrate content.

Regarding the T x Cv interaction, $N_{100+50}P_{60}K_{30}$ x Delfin, $N_{100}P_{60}K_{30}$ x Delfin and $N_{100+50}P_{60}K_{30}$ x Driera gave the highest values for total carbohydrate and they were

Table 28. Effect of two doses of basal phosphorus applied with two doses of basal nitrogen on total grain carbohydrate content (%) of four cultivars of triticale and a wheat check. (Mean of three replicates)

Cultivars	Treatments (kg $N+P_2O_5$/ha)				
	100+45	100+60	150+45	150+60	Mean
Wheat	76.32	77.78	77.13	78.08	77.33
Delfin	77.54	79.20	77.97	79.59	78.58
Driera	74.69	77.07	76.46	78.88	76.78
TL-419	72.20	75.07	73.84	75.95	74.26
Tigre'S'	72.99	75.15	73.88	76.20	74.56
Mean	74.75	76.86	75.86	77.74	

N.B. 30 kg K/ha was applied uniformly at the time of sowing.

	C.D.at 5%
Treatments	0.20
Cultivar	0.23
Treatment x Cultivar	0.46

statistically equal in their effect. The treatment $N_{100}P_{45}K_{30}$ x TL-419 gave the lowest value for the parameter (Table 28).

4.2 EXPERIMENT 2

This second factorial randomised field experiment was conducted with the aim to select the best stage(s) for the application of supplemental phosphorus spray in the form of monocalcium superphosphate. In all, eight treatments were tested (Table 3) including spray of de-ionised water (control). The stage at which phosphorus sprays were applied included tillering (T), heading (H), milky grain (M), tillering and heading (TH), tillering and milky grain (TM), heading and milky grain (HM) and tillering, heading and milky grain (THM).

4.2.1 Yield characteristics

After harvest, various yield parameters were studied. The data, summarised in Tables 29-42, are described briefly below:

4.2.1.1 Ear number per plant

The effect of phosphorus spray on ear production was significant (Table 29). The values obtained for THM were at par. In terms of percentage, the treatment THM gave 29.41% more ears than the water-sprayed control.

Table 29. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on ear number per plant. (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	8.33	8.67	8.50
Tillering	(T)	8.67	9.67	9.17
Heading	(H)	8.33	9.00	8.67
Milky grain	(M)	8.67	8.67	8.67
Tillering+heading	(TH)	9.67	11.67	10.67
Tillering+Milky grain	(TM)	9.67	12.00	10.83
Heading+Milky grain	(HM)	8.67	9.33	9.00
Tillering+heading+ Milky grain	(THM)	9.67	12.33	11.00
Mean		8.96	10.17	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.65
Cultivar	0.32
Treatment x Cultivar	0.92

Among the two cultivars, Delfin gave 13.50% more ears per plant than wheat.

Considering the T x Cv interaction effect, THM x Delfin, TH x Delfin and TM x Delfin, being at par, produced more ears than the other combinations. It is noteworthy that wheat interacted less favourably with phosphorus spray than Delfin at almost all stages with regard to ear production.

4.2.1.2 Ear weight per plant

The effect of phosphorus spray on ear weight per plant was significant (Table 30). Among the eight treatments, spray of phosphorus at all three growth stages (THM), followed by HM and TM that were at par in their effect, proved most effective. The values recorded for these treatments were 44.00% and more than 38% higher than that of the control.

Among the cultivars, the ear weight per plant was 48.59% higher compared with wheat.

T x Cv interaction effect was also significant THM x Delfin (at par with HM x Delfin) proved the most effective combinations and yielded maximum ear weight per plant (83.79%) more than water spray x wheat that proved the poorest combination.

Table 30. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on ear weight per plant (g). (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	24.98	26.55	25.77
Tillering	(T)	25.12	31.39	28.26
Heading	(H)	25.95	37.31	31.63
Milky grain	(M)	25.97	43.71	34.84
Tillering+Heading	(TH)	26.32	38.99	32.66
Tillering+Milky grain	(TM)	27.09	44.01	35.55
Heading+Milky grain	(HM)	26.81	45.01	35.91
Tillering+Heading+ Milky grain	(THM)	28.30	45.91	37.11
Mean		26.32	39.11	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.70
Cultivar	0.35
Treatment x Cultivar	0.99

4.2.1.3 Length per ear

Phosphorus spray significantly affected ear length also (Table 31). Among the eight spray treatments tried, spray at tillering heading and milky grain stage (THM) produced the longest ears, followed by that at heading and milky grain stage (HM) and gave 24.84% and 13.52% longer ears respectively than the control sprayed with water.

On comparing triticale with wheat, Delfin showed 39.49% increase in ear length over wheat.

As regards T x Cv interaction effect, THM with Delfin gave 73.24% longer ears than the combination control with wheat, that gave the lowest value. It was followed by HM x Delfin that gave 60.57% longer ears than water x wheat.

4.2.1.4 Spikelet number per ear

Number of spikelets per ear was significantly affected by the phosphorus sprays (Table 32). All the treatments gave higher values than the water-sprayed control with THM, followed by TH and HM (at par), proving the most effective. THM produced 64.60% and TH and HM, about 40% more spikelets than the control.

Like the other yield parameters, Delfin again surpassed the wheat check by producing 84.96% more spikelet per ear.

Table 31. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on length per ear (cm). (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	14.61	19.84	17.23
Tillering	(T)	14.69	19.83	17.26
Heading	(H)	14.66	20.39	17.53
Milky grain	(M)	14.65	19.79	17.22
Tillering+Heading	(TH)	15.42	22.76	19.09
Tillering+Milky grain	(TM)	15.54	20.11	17.83
Heading+Milky grain	(HM)	15.65	23.46	19.56
Tillering+Heading+ Milky grain	(THM)	17.70	25.31	21.51
Mean		15.37	21.44	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D. at 5%
Treatments	0.18
Cultivar	0.09
Treatment x Cultivar	0.25

Table 32. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on spikelet number per ear. (Mean of three replicates)

Treatments		Crop: Wheat (HD-2204)	Crop: Triticale (Delfin)	Mean
Control	(C)	17.67	25.67	21.67
Tillering	(T)	18.67	34.33	26.50
Heading	(H)	20.33	36.33	28.33
Milky grain	(M)	19.67	33.67	26.67
Tillering+Heading	(TH)	20.67	40.33	30.50
Tillering+Milky grain	(TM)	20.33	35.67	28.00
Heading+Milky grain	(HM)	19.67	40.67	30.17
Tillering+Heading+ Milky grain	(THM)	22.67	48.67	35.67
Mean		19.96	36.92	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D. at 5%
Treatments	1.15
Cultivar	0.58
Treatment x Cultivar	1.63

All the T x Cv interactions for triticale were better than the respective combinations with wheat. The maximum number of spikelets was obtained with THM x Delfin. It proved 64.61% more effective than water x wheat and was followed by HM x Delfin.

4.2.1.5 Grain number per ear

Foliar spray of phosphorus significantly increased grain number per ear (Table 33). Most of the treatments, except M and TH which were at par, were critically different in their effect. Treatment THM resulted in 49.59% more grains per ear than the water-sprayed control. It was followed by TM and HM, in that order.

Triticale cultivar Delfin produced 18.18% more grains per ear than HD-2204 wheat.

The combination THM x Delfin proved most effective, followed by HM x Delfin. These produced 71.18% and 53.10% more grains than water x wheat, that gave the lowest value.

4.2.1.6 1,000 grain weight

1,000 grain weight, was also affected significantly by the phosphorus sprays (Table 34). THM, closely followed by HM, proved most effective. An increase of 21.62% in 1,000 grain weight over the control was recorded by THM. Treatment HM increased 1,000 grain weight by 20.43% over the water-sprayed control.

Table 33. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on grain number per ear. (Mean of three replicates)

Treatments		Crop: Wheat (HD-2204)	Crop: Triticale (Delfin)	Mean
Control	(C)	59.00	65.33	62.17
Tillering	(T)	63.67	70.67	67.17
Heading	(H)	64.33	76.33	70.33
Milky grain	(M)	63.67	82.00	72.83
Tillering+Heading	(TH)	70.33	74.00	72.17
Tillering+Milky grain	(TM)	76.67	86.33	81.50
Heading+Milky grain	(HM)	64.00	90.33	77.17
Tillering+Heading+ Milky grain	(THM)	85.00	101.00	93.00
Mean		68.33	80.75	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	2.38
Cultivar	1.19
Treatment x Cultivar	3.36

Table 34. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on 1,000 grain weight (g). (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	45.65	48.21	46.93
Tillering	(T)	46.91	48.83	47.87
Heading	(H)	52.19	50.15	51.17
Milky grain	(M)	53.67	56.86	55.27
Tillering+Heading	(TH)	52.39	54.93	53.66
Tillering+Milky grain	(TM)	53.70	57.13	55.42
Heading+Milky grain	(HM)	55.45	57.58	56.52
Tillering+Heading+ Milky grain	(THM)	55.49	58.66	57.08
Mean		51.93	54.04	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.27
Cultivar	0.14
Treatment x Cultivar	0.38

Delfin recorded 4.06% higher, 1,000 grain weight than wheat.

T x Cv interaction effect was significant, Out of all the combinations, THM x Delfin proved best, followed by HM x Delfin, the respective increase in 1,000 grain weight over water x wheat (that was the least effective) being 28.49% and 26.13%.

4.2.1.7 <u>Grain yield</u>

Phosphorus spray significantly increased grain yield (Table 35). THM and HM, being at par, proved most effective and produced 28.75% more grain than the control sprayed with water.

Delfin proved 22.32% better in terms of grain production compared with wheat check.

Among the interactions, THM x Delfin and HM x Delfin, being at par, proved the best combination for grain yield and produced about 55% more grain than water x wheat.

4.2.1.8 <u>Straw yield</u>

Production of straw was also affected significantly (Table 36). THM gave 13.40% more straw, followed by TH (11.06%), TM (8.14%) and T (5.84% more) than the control. It is noteworthy that the treatment HM, that proved highly

Table 35. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on grain yield (q/ha). (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	36.79	43.83	40.31
Tillering	(T)	37.00	46.34	41.67
Heading	(H)	40.31	48.30	44.30
Milky grain	(M)	44.32	55.48	49.90
Tillering+Heading	(TH)	40.90	48.44	44.67
Tillering+Milky grain	(TM)	44.85	55.46	50.16
Heading+Milky grain	(HM)	46.13	56.88	51.50
Tillering+Heading+ Milky grain	(THM)	46.54	57.25	51.90
Mean		42.10	51.50	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.51
Cultivar	0.26
Treatment x Cultivar	0.73

Table 36. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on straw yield (q/ha). (Mean of three replicates)

Treatments		Crop: Wheat (HD-2204)	Crop: Triticale (Delfin)	Mean
Control	(C)	116.10	118.20	117.15
Tillering	(T)	110.41	137.59	124.00
Heading	(H)	113.17	120.36	116.77
Milky grain	(M)	108.17	120.75	114.46
Tillering+Heading	(TH)	117.49	142.73	130.11
Tillering+Milky grain	(TM)	117.32	136.07	126.69
Heading+Milky grain	(HM)	119.35	124.99	122.17
Tillering+Heading+ Milky grain	(THM)	118.44	147.26	132.85
Mean		115.06	130.99	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.49
Cultivar	0.24
Treatment x Cultivar	0.69

effective for all other yield parameters (including grain yield), was not very effective for straw production and resulted in only 4.28% increase over the control.

As far as crop response was concerned, triticale cultivar Delfin produced 13.84% higher straw than the wheat.

Considering T x Cv interaction effect, THM x Delfin proved most effective. The straw yield noted in this combination was 26.83% more than that for water x wheat. It may be noted that straw production was more in all the spray treatment combinations with triticale in comparison to the corresponding treatment x wheat combinations. Also, all treatments comprising spray at tillering (T, TH, TM and THM) interacted better (particularly with Delfin) than H, M and HM.

4.2.2 <u>Grain analysis</u>

To test the efficacy of phosphorus spray on the grain quality of triticale cultivar (Delfin) and wheat cultivar (HD-2204), the grains were chemically analysed for their protein and carbohydrate contents and the findings (recorded in Table 37-42) are described below:

4.2.2.1 <u>Soluble protein content</u>

Spray of phosphorus in the form of dilute aqueous solution at different growth stages was beneficial for increasing the grain soluble protein content (Table 37). Among the treatments, spray of phosphorus at THM proved most effective and was closely followed by that at HM. The respective values were 16.25% and 14.19% more in comparison to control.

Cultivars responded significantly to the spray treatment and Delfin grain possessed 15.99% more soluble protein than wheat grain.

Regarding T x Cv interaction effect, THM x Delfin proved the most effective combination and was closely followed by HM x Delfin and proved superior over water x wheat combination. The values recorded for THM x Delfin and HM x Delfin were 39.26% and 35.61% more than for water x wheat.

4.2.2.2 Insoluble protein content

In general, spray of phosphorus significantly affected the grain insoluble protein (Table 38). Treatment THM proved most effective and resulted in 16.75% more insoluble protein than the control. Spray at heading and milky grain stages (HM) was also beneficial and produced 12.64% higher insoluble protein over the control, which had the lowest insoluble protein content in its grain.

Delfin grain had 9.29% more insoluble protein than the wheat check.

Table 37. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on soluble grain protein content(%). (Mean of three replicates)

Treatments		Crop: Wheat (HD-2204)	Crop: Triticale (Delfin)	Mean
Control	(C)	4.38	5.34	4.86
Tillering	(T)	4.71	5.47	5.09
Heading	(H)	4.91	5.65	5.28
Milky grain	(M)	4.95	5.67	5.31
Tillering+Heading	(TH)	5.09	5.85	5.47
Tillering+Milky grain	(TM)	5.13	5.86	5.49
Heading+Milky grain	(HM)	5.16	5.94	5.55
Tillering+Heading+ Milky grain	(THM)	5.20	6.10	5.65
Mean		4.94	5.73	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.03
Cultivar	0.02
Treatment x Cultivar	0.05

Table 38. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on insoluble grain protein content(%).(Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	8.07	8.65	8.36
Tillering	(T)	8.24	9.03	8.64
Heading	(H)	8.34	9.23	8.79
Milky grain	(M)	8.88	9.52	9.20
Tillering+Heading	(TH)	8.93	9.67	9.30
Tillering+Milky grain	(TM)	8.93	9.74	9.34
Heading+Milky grain	(HM)	9.06	10.07	9.57
Tillering+Heading+ Milky grain	(THM)	9.24	10.27	9.76
Mean		8.71	9.52	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatment	0.04
Cultivar	0.02
Treatment x Cultivar	0.06

Considering the T x Cv interactions, Delfin x THM proved the best combination and resulted in 27.26% more insoluble protein compared to water x wheat. Other combinations were also critically different like HM x Delfin, TM x Delfin, TH x Delfin and M x Delfin and their respective values were 24.78%, 20.69%, 19.83% and 17.96% more than that of water x wheat. Interestingly Delfin interacted with the treatments better than the respective treatment x wheat.

4.2.2.3 Total protein content

As in the case of soluble and insoluble grain protein, total protein content of grain was highest in treatment THM, followed closely by treatment HM. These gave 16.56% and 14.37% higher values than the control sprayed with water, that gave the lowest value for total grain protein content (Table 39).

Delfin possessed 11.72% more total protein in the grain than wheat check.

Among the treatment x Cv interactions, the highest value was given by THM x Delfin, followed closely by HM x Delfin and the lowest, by water x wheat (Table 39).

4.2.2.4 Soluble carbohydrate content

Soluble carbohydrate of the grain was significantly affected by phosphorus spray at various growth stages (Table 40).

Table 39. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on total grain protein content (%). (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	12.45	13.99	13.22
Tillering	(T)	12.95	14.50	13.73
Heading	(H)	13.25	14.88	14.07
Milky grain	(M)	13.83	15.19	14.51
Tillering+Heading	(TH)	14.02	15.52	14.77
Tillering+Milky grain	(TM)	14.06	15.60	14.83
Heading+Milky grain	(HM)	14.22	16.01	15.12
Tillering+Heading+ Milky grain	(THM)	14.44	16.37	15.41
Mean		13.65	15.25	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D. at 5%
Treatments	0.08
Cultivar	0.04
Treatment x Cultivar	0.13

Table 40. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on soluble grain carbohydrate content (%). (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	4.18	6.23	5.21
Tillering	(T)	4.63	6.30	5.46
Heading	(H)	4.82	6.61	5.72
Milky grain	(M)	4.98	6.83	5.91
Tillering+Heading	(TH)	5.11	6.97	6.04
Tillering+Milky grain	(TM)	5.50	7.30	6.40
Heading+Milky grain	(HM)	6.02	7.72	6.87
Tillering+Heading+ Milky grain	(THM)	5.68	7.34	6.51
Mean		5.12	6.91	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.06
Cultivar	0.03
Treatment x Cultivar	0.08

All the treatments were critically different in their effect. Treatment (HM) proved most effective for increasing the soluble carbohydrate content and resulted in 31.86% higher value than the control. It was followed by THM which gave 24.95% higher soluble carbohydrate content over control. The rest of the treatments like TM, TH, M, H and T resulted in 22.84%, 15.93%, 13.44%, 9.79% and 4.80% higher grain soluble carbohydrate content respectively than the control.

Regarding cultivar response, Delfin recorded 34.96% more soluble carbohydrate compared with wheat.

The sixteen possible combinations of T x Cv interactions had significant effect and most of them critically different from each other in this respect. Combination HM x Delfin proved best giving 84,68% higher soluble carbohydrate content than the water x wheat. The values obtained by the combination of THM x Delfin and TM x Delfin were at par.

4.2.2.5 Insoluble carbohydrate content

Spraying the plants with phosphorus resulted in significant increase in grain insoluble carbohydrate (Table 41).

Among the treatments, spray of phosphorus at all the growth stages were critically different in their effects. The treatment THM proved most effective and gave 5.81% more insoluble carbohydrate content compared to control. On the

Table 41. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on insoluble grain carbohydrate content (%). (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	69.24	69.93	69.59
Tillering	(T)	69.57	70.52	70.05
Heading	(H)	69.83	70.59	70.21
Milky grain	(M)	70.13	71.33	70.73
Tillering+Heading	(TH)	70.70	72.39	71.55
Tillering+Milky grain	(TM)	71.14	72.74	71.94
Heading+Milky grain	(HM)	72.92	74.09	73.50
Tillering+Heading+ Milky grain	(THM)	72.67	74.62	73.64
Mean		70.75	72.03	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.06
Cultivar	0.03
Treatment x Cultivar	0.09

other hand, TM that followed it closely, resulted in 5.62% more insoluble carbohydrate content than the control.

On comparing the two crops tested, Delfin proved superior exhibiting 1.81% higher insoluble carbohydrate content than wheat.

The T x Cv interaction THM x Delfin was 7.77% superior to the water x wheat interaction regarding this parameter.

4.2.2.6 Total carbohydrate content

A perusal of Table 42 clearly establishes that treatment HM resulted in the highest total grain carbohydrate content (7.45% better than control), closely followed by THM (7.15% higher than control). In fact, the effect of the treatments exhibited the same pattern for this parameter as for soluble carbohydrates (Table 40).

Delfin possessed 4.05% more total grain carbohydrate than wheat.

Among the interaction effects (T x Cv), THM x Delfin, followed very closely by HM x Delfin gave the highest value and water x wheat, the lowest value for total grain carbohydrate content (Table 42).

Table 42. Effect of supplemental phosphorus spray at various growth stages of triticale and wheat on total grain carbohydrate content (%). (Mean of three replicates)

Treatments		Crop		Mean
		Wheat (HD-2204)	Triticale (Delfin)	
Control	(C)	73.42	76.16	74.80
Tillering	(T)	74.10	76.82	75.51
Heading	(H)	74.65	77.20	75.93
Milky grain	(M)	75.11	78.16	76.64
Tillering+Heading	(TH)	75.81	79.36	77.59
Tillering+Milky grain	(TM)	76.64	80.04	78.34
Heading+Milky grain	(HM)	78.94	81.81	80.37
Tillering+Heading+ Milky grain	(THM)	78.35	81.96	80.15
Mean		75.87	78.94	

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at the time of sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in one, two or three equal splits.

	C.D.at 5%
Treatments	0.09
Cultivar	0.04
Treatment x Cultivar	0.13

4.3 EXPERIMENT 3

The aim of this simple rendomised trial was to confirm the findings of Experiment 2 regarding the response of Delfin to the spray of monocalcium superphosphate applied at heading and milky grain stages. In addition, the effect of this treatment was compared with that of two other sources of phosphorus, namely diammonium phosphate and sodium dihydrogen orthophate.

4.3.1 Yield characteristics

The comparative response of triticale cultivar Delfin with regard to various yield parameters, studied at harvest (Table 43) as described below:

4.3.1.1 Ear number per plant

Ear production was significantly affected by the spray treatments and monocalcium superphosphate spray proved the most effective source of phosphorus. The other two sources (NaH_2PO_4 and DAP) were equal in their effect. Spray of deionised water (control) resulted in the lowest number of ears per plant. It may be noted from Table 43 that compared with the control, superphosphate spray produced 36.49% more ears and the other two treatments about 15.56% more.

4.3.1.2 Ear weight per plant

Among the various treatments, superphosphate spray gave the highest value for ear weight (Table 43). It was

Table 43. Effect of spray of three sources of phosphorus on the yield characteristics of triticale cv. Delfin. (Means of three replicates)

Characteristics	De-ionised water (Control)	Sources of phosphorus			C.D. at 5%
		NaH_2PO_4	DAP	Superphosphate	
Ear number per plant	8.74	10.10	10.56	11.93	0.71
Ear weight per plant (g)	32.39	35.75	41.40	46.45	1.10
Length per ear (cm)	18.98	21.50	22.10	22.90	1.55
Spikelet number per ear	33.21	34.97	35.97	37.48	1.45
Grain number per ear	76.00	77.15	77.94	80.42	1.40
1,000 grain weight (g)	49.82	50.49	52.99	53.91	1.05
Grain yield (q/ha)	34.60	37.14	38.20	57.76	1.66
Straw yield (q/ha)	84.70	92.57	93.79	92.78	2.85

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in two equal splits at heading and milky grain stages.

followed by diammonium phosphate (DAP) and sodium dihydrogen orthophosphate(NaH_2PO_4)spray, in that order. It was increased by 43.41%, 27.82% and 10.37% by superphosphate. DAP and NaH_2PO_4 respectively over the control, which gave the lowest ear weight.

4.3.1.3 Length per ear

Ear length was significantly affected by the spray treatments. However, superphosphate was as effective in enhancing it as DAP and NaH_2PO_4, the increase being more than 13.28% than the ear length in the water sprayed control.

4.3.1.4 Spikelet number per ear

Like the other yield parameters mentioned above, superphosphate spray proved most effective for the increase in number of spikelets per ear, showing 12.85% increase over the control. It was followed by the application of DAP and NaH_2PO_4, which were at par and showed an increase of more than 5.29% compared with the effect of water spray (Table 43).

4.3.1.5 Grain number per ear

Significant increase in grain number per ear as a result of spray treatments is revealed by Table 43. The value recorded for superphosphate spray was 5.81% more than that for control. NaH_2PO_4 was at par with DAP spray as well as water spray in its effect. The value for DAP was 2.55% higher in comparison with control.

4.3.1.6 1,000 grain weight

Maximum 1,000 grain weight was recorded in superphosphate spray, but it was at par with that due to DAP spray. This treatment enhanced seed weight by 8.21% when compared with control. On the other hand, NaH_2PO_4 spray seemed to have no effect on this parameters, as it proved at par with the spray of de-ionised water, like grain number per ear (Table 43).

4.3.1.7 Grain yield

Like the other yield parameters mentioned earlier, grain yield was maximum when the crop was sprayed with aqueous solution of superphosphate. It was critically different from those in the remaining treatments and gave 66.9% higher grain yield than the control. Diammonium phosphate and sodium dihydrogen orthophosphate were equally effective in terms of grain production, being about 7-10% more effective than the deionised water sprayed control, which was the poorest in its effect (Table 43).

4.3.1.8 Straw yield

Spray proved significantly superior to the control for straw production,which was more than 9% higher than in the control. However, superphosphate, DAP and NaH_2PO_4 treatments were at par in their effect. The straw yield was poorest in the control (Table 43).

4.3.2 Grain analysis

For the assessment of the quality of triticale grain, the following parameters were chemically analysed. The data summarised in Table 44 and are considered below:

4.3.2.1 Soluble protein content

It was significantly affected by the spray treatments and it was maximum in monocalcium superphosphate, followed by diammonium phosphate and sodium dihydrogen orthophosphate, which were at par in their effect on the soluble protein content of the grain. The increase was 6.20%, when sprayed with superphosphate and more than 2% in the case of DAP and NaH_2PO_4 spray compared with control.

4.3.2.2 Insoluble protein content

Insoluble protein content, was significantly affected by the spray treatments and superphosphate spray gave the highest value. Superphosphate, DAP and NaH_2PO_4 produced 7.15%, 5.31% and 4.44% respectively more soluble protein over the water sprayed control (Table 44).

4.3.2.3 Total protein content

Table 44 clearly indicates that the effect of the treatments on this parameter of grain quality presented a picture very similar to that for insoluble protein content of

Table 44. Effect of spray of three sources of phosphorus on the grain quality characteristics of triticale cv. Delfin. (Mean of three replicates)

Characteristics	De-ionised water (Control)	Sources of phosphorus			C.D.at 5%
		NaH_2PO_4	DAP	Superphosphate	
Soluble protein content (%)	5.64	5.75	5.77	5.99	0.05
Insoluble protein content (%)	9.22	9.63	9.71	9.88	0.03
Total protein content (%)	14.86	15.38	15.48	15.87	0.09
Soluble carbohydrate content (%)	4.82	5.11	5.53	6.85	0.05
Insoluble carbohydrate content (%)	71.19	71.25	72.07	75.78	0.13
Total carbohydrate content (%)	76.01	76.36	77.60	82.63	0.20

N.B. A uniform dose of 100 kg N, 45 kg P_2O_5 and 30 kg K/ha was applied at sowing, followed by 50 kg N/ha by top-dressing at tillering.

The quantity of phosphorus in the spray was 4 kg/ha applied in two equal splits at heading and milky grain stages.

grain. Thus, spray of superphosphate significantly increased it by 6.80%, followed by DAP (4.17%) and NaH_2PO_4 (3.50%) over the water-sprayed control, that possessed the lowest total grain protein percentage.

4.3.2.4 Soluble carbohydrate content

Maximum soluble carbohydrate was recorded in superphosphate spray, followed by DAP and NaH_2PO_4 in that order (Table 44). The increase was 42.11%, 14.73% and 6.01% by superphosphate, DAP and NaH_2PO_4 respectively over the control.

4.3.2.5 Insoluble carbohydrate content

Significant increase was found in the insoluble carbohydrate content of grain by the spray. Application of superphosphate spray produced 6.44% more insoluble carbohydrate than that of deionised water. The value for DAP spray was 1.23% more than that for the control, while the effect of NaH_2PO_4 was statistically equal to that of control (Table 44).

4.3.2.6 Total carbohydrate content

A perusal of Table 44 shows that the effect of treatments on the total grain carbohydrate content was significant and followed the same general pattern as that of soluble carbohydrate. Thus, spray of superphosphate was 18.70% more effective for this parameter, whereas DAP showed an improvement of 12.09% and NaH_2PO_4 of only 0.46%,than spray of water.

4.4 Milling and baking quality

The comparative performance of triticale and wheat regarding flour extraction was noted and it was found that triticale cultivar Delfin gave 8.00 kg flour (80%) while wheat cultivar HD-2204 gave 8.50 kg flour (85%) out of 10 kg of triticale and wheat grains. The colour of the flour obtained from triticale was darker than that of wheat.

4.4.1 Visual observation of loaf

In external appearance, the loaves prepared with 100% triticale flour, 100% wheat flour and their blend consisting of 50% wheat flour + 50% triticale flour were almost similar (Plates 1-4).

4.4.1.2 Sensory evaluation of loaf

Sensory evaluation was also made for the softness and flavour of loaf and the data were analysed and tabulated (Table 45). It was significant for both the characters studied. The value regarding the softness of loaves of triticale flour were at par with the softness of the blend and those for the softness of the blend were at par with the values for the softness of loaves of wheat. However, a significant difference in softness was noted when triticale (100%) was compared with wheat (100%). Flavour of loaves of wheat and loaves of the blend were equal in their values,

PLATE 1

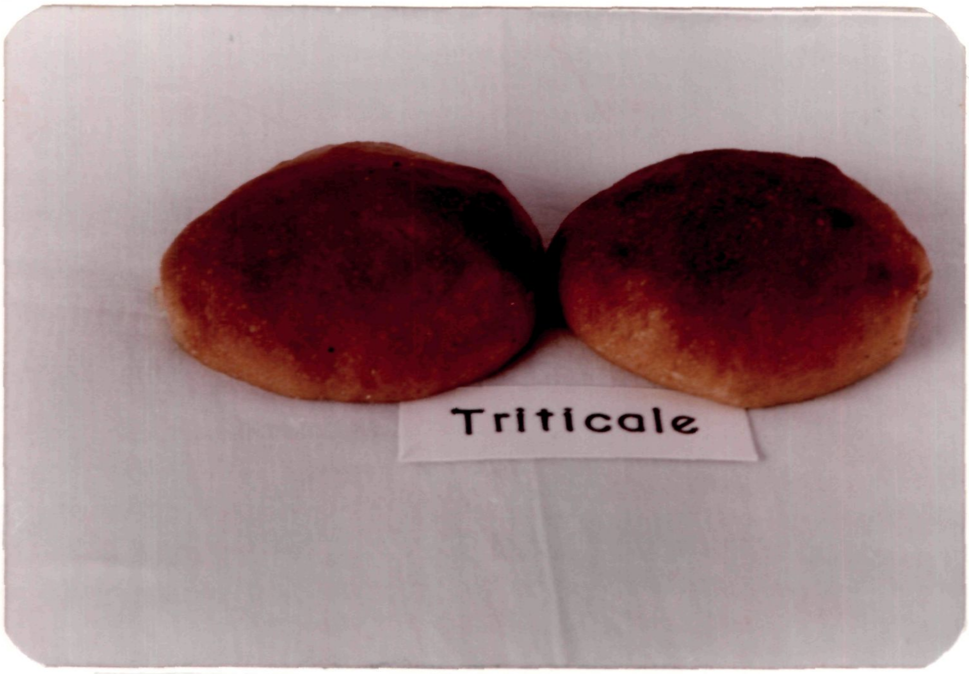


PLATE 2

PLATE 3

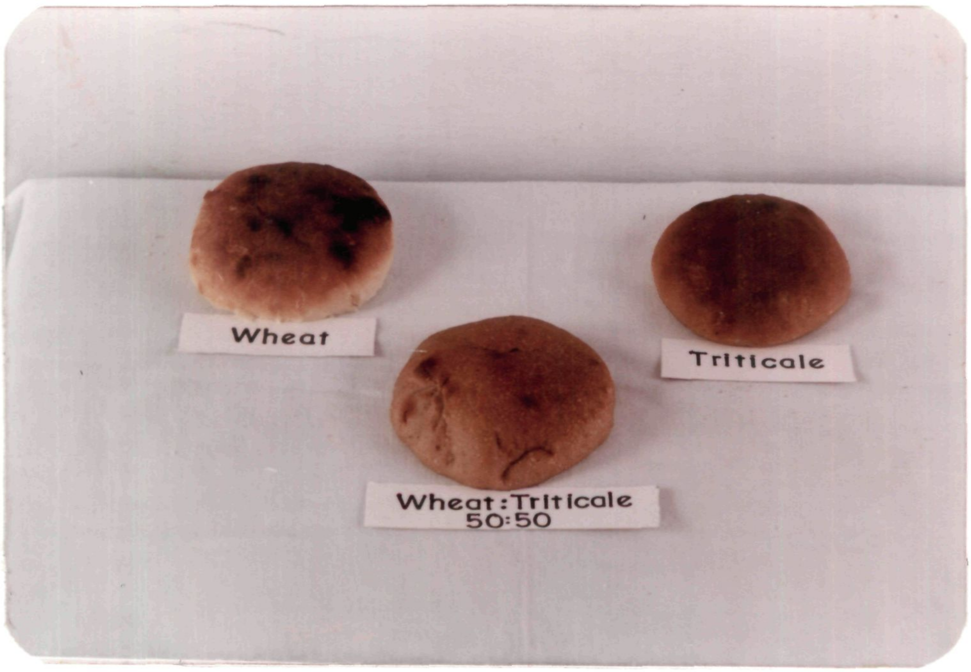


PLATE 4

Table 45. Sensory evaluation of bun (Mean of thirty replicates)

Characteristics	Crops			C.D. at 5%
	Wheat (HD-2204)	Triticale (Delfin)	Blend (1:1)	
Softness	2.0	3.5	2.7	0.89
Flavour	1.53	4.0	2.2	1.5

N.B. Lower rating indicates better performance.

but the loaves of 100% triticale flour were noted to give comparatively poor performance.

4.4.1.3 Visual observation of chapatti

The colour of the chapattis was different in all the three samples (Plates 5 - 8). Wheat flour was distinctly the whitest. It was noted that while the boundries of the chapattis made from it were intact and smooth, those made from triticale flour were light brown with broken edges while the blended flour gave comparatively lighter coloured chapattis with smooth margin.

4.4.1.4 Sensory evaluation of chapattis

The results regarding the softness and flavour of the chapattis of the three samples were statistically analysed (Table 46) and it was noted that the difference was non-significant for the softness of chapattis. However, it was significant for flavour. The flavour of chapattis of wheat flour was at par with that of chapattis made of blended flour. Chapattis made from 100% triticale flour were different in their taste and not liked but the chapattis of the blended flour were not only acceptable but also appreciated.

PLATE 5

PLATE 6

PLATE 7

PLATE 8

Table 46. Sensory evaluation of chapatti (Mean of thirty replicates)

Characteristics	Crops			C.D. at 5%
	Wheat (HD-2204)	Triticale (Delfin)	Blend (1:1)	
Softness	2.80	3.53	3.00	N.S.
Flavour	1.33	3.50	1.83	1.46

N.B. Lower rating indicates better performance.

N.S. - Non significant.

CHAPTER 5

DISCUSSION

CONTENTS

DISCUSSION

5.1 Introduction

Being a newly introduced and commercially less viable crop, triticale has received far less attention of farm scientist than most of the traditional cereals. Whatever interest is discernible during the short history of this fascinating crop is that among plant breeders as plant nutrition specialists and agronomists have not been able to keep pace with them both in India as well as in other parts of the world. None the less, the release of newer improved cultivars at a rapid pace during the last two or three decades has been instrumental in spurring a few workers to determine their optimum fertiliser requirements, particularly that of nitrogen (Ali and Rajput, 1978; Etchevers and Morghan, 1978; Gajardo et al., 1978; Kalra and Dhiman, 1979; Bishnoi and Mugwira, 1980; Farnworth and Said, 1982; Graham et al., 1983; Bali et al.,1991). It may be pointed out, however, that the laboratory of Plant Nutrition at Aligarh Muslim University, Aligarh (India) has paid considerable attention to this neglected aspect since the early 1970's. Afridi, Samiullah, Inam and their associates have embarsked upon an ambitious project to investigate various aspects of the mineral nutrition of triticale (Siddiqui, 1974; Inam, 1978; Abbas, 1980; Alvi, 1984; Ashfaq, 1986; Moinuddin, 1987; Aziz, 1991).

As part of the on-going studies, the present author decided to fill some of the lacunae regarding the phosphorus nutrition of the newly released cultivars of triticale. It may be worthwhile to recall at this stage that the study comprised three field experiments of which the first was a comprehensive trial on four such cultivars to study their performance in comparison with a locally popular wheat check under two levels of basally applied phosphorus. The criteria for selecting the best responding cultivar were: growth characteristics, leaf -N, -P, and -K contents, leaf NRA, yield characteristics and grain quality. The data revealed the superiority of Delfin over the other cultivars, including the wheat check, particularly when grown with the higher dose of phosphorus (P_{60}). The next two experiments were, therefore, confined to the cultivar Delfin to test its yielding ability under constraints of phosphatic fertiliser application by supplementing a sub-optimal basal dose with spray of a small quantity of phosphorus at various growth stages. The results confirmed the versatility of Delfin and also established that considerable quantities of costly phosphatic fertiliser could be saved without sacrificing grain yield and quality. In what follows hereafter, the physiological implications of the data of all the three trials are discussed together parameter-wise for the sake of convenience.

5.2 Growth characteristics

The growth parameters selected for Experiment 1 included some of the most important morphophysiological attributes of a cereal crop. As stated by Gregory (1937), whereas shoot length and tiller number are a measure of meristematic activity, increase in the number of leaves at different stages indicates the degree of differentiation and photosynthetic rate and fresh and dry weight account for total productivity of the plant. It is, therefore, logical to conclude that the yield of a crop is the manifestation of their cumulative effect through their influence on the yield attributing characteristics. More recently, Bunting and Drennan (1966) have emphasised that " the vegetative stage may have an important and direct effect on grain yield" . The review by Yoshida (1972) also highlights this assertion.

The data of Experiment 1 confirm these generalisation explicitly. The two doses of basal phosphorus i.e. 45 kg P_2O_5/ha (P_{45}) and 60 kg P_2O_5/ha (P_{60}) were selected so as to assess critically the phosphorus requirement of the cultivars under local agro-climatic conditions. In this cultivar-cum-fertiliser trial, P_{60} (the higher dose of basal phosphorus), proved more beneficial than P_{45} for shoot length (Table 6), tiller number (Table 7), leaf number (Table 8), fresh weight (Table 9) and dry weight (Table 10) of the plant at all three stages. These data confirm the well established role of phosphorus in cell division and expansion (Hewitt, 1963; Black, 1968; Patnaik, 1987). Adequate provision of the nutrient at sowing through application of P_{60} promoted tissue and organ formation and growth, culminating in enhanced leaf and tiller formation (Tamhane et al., 1970). Expectedly, the resulting increased photosynthetic area would have a higher photosynthetic rate as reported for phosphorus application by Natr (1972), Osman et al. (1977), Longstreth and Nobel (1980) and produce more dry matter which is the best measure of plant vigour. This is vividly brought out by the study of correlation coefficient (r) of various growth parameters with the dry weight of plants at the three stages of growth. Table 47 reveals that each growth parameter was highly associated ($P=0.01$) with the dry weight of plants, particularly at the heading stage of growth. The economic importance of this observation cannot be over-emphasised as, according to Milthorpe and Moorby (1979), the potential yield of a crop is determined during the early stage of inflorescence differentiation.

It is also noteworthy that after the addition of 50 kg N/ha as top-dressing at the tillering stage, the crop exhibited a well-defined synergistic effect between applied phosphorus and nitrogen, as phosphorus and nitrogen are known to accelarate root proliferation (Grunes and Krantz, 1958), thus facilitating the uptake nutrients and water. More over, nitrogen application is known to have a pronounced effect on leaf area (Humphries and Wheeler, 1963; Gardner et al., 1985). Thus, it is not

Table 47. Correlation coefficient (γ) between growth parameters and dry weight at three growth stages (Experiment 1).

Parameters	Stages	γ value
Shoot length	Tillering	0.5513^{*}
	Heading	0.6906^{**}
	Milky grain	0.5018^{*}
Tiller number	Tillering	0.6523^{**}
	Heading	0.8234^{**}
	Milky grain	0.8001^{**}
Leaf number	Tillering	0.7839^{**}
	Heading	0.6836^{**}
	Milky grain	0.5417^{*}
Fresh weight	Tillering	0.8474^{**}
	Heading	0.8965^{**}
	Milky grain	0.9953^{**}

** Significant at 0.01%

* Significant at 0.05%

surprising that $N_{100+50}P_{60}$ enhanced maximally all growth parameters in the samples collected at heading and milky grain stages (Tables 6–10). To summarise, the data regarding the response to the treatments in this trial highlight the following interesting points:

(a) Supplementing the basal dose of nitrogen (N_{100}) with 50 kg N/ha by top-dressing proved inadequate with the lower dose of phosphorus (P_{45}), this combination ($N_{100+50}P_{45}$) being at par with $N_{100}P_{60}$ for tiller and leaf production at heading stage (Table 7 and 8) which clearly indicates the importance of phosphorus for tiller and leaf formation.

(b) On the other hand, the same operation i.e. applying 50 kg N/ha by top-dressing at the tillering stage to plants raised with N_{100}, the higher basal dose of phosphorus (P_{60}) resulted not only in maximisation of tiller and leaf production but also of the height, fresh weight and dry weight of plants.

The observations confirm the beneficial role of phosphorus in the presence of sufficient quantities of nitrogen in various processes of growth. In this connection it is relevant to emphasise that balanced nutrition plays an indispensable role in bringing about the full realisation of the genetic potential with respect to the growth and development of a crop (Milthorpe and Moorby, 1979; Noggle and Fritz, 1986). Therefore, application of $N_{100+50}P_{60}$ (in the presence of K_{30}

added uniformly) may be considered a balanced fertiliser treatment under local conditions.

Regarding the cultivar differences, Delfin gave the maximum values for almost all the growth parameters at each stage, while TL-419 triticale and HD-2204 wheat followed it and Tigre'S' gave the lowest values (Tables 6-10). The better growth performance of Delfin compared with the wheat check would be expected as HD-2204 is a dwarf cultivar of wheat, with a lower inherent capacity for tiller (Table 7) and leaf (Table 8) production. As indicated by Tables 9 and 10, maximum fresh weight and dry weight was also noted in Delfin. This might be due to its greater photosynthetic area (Moss, 1988) because of its highest number of tiller and leaves at all the stages noted above. The present data thus confirm the findings on triticale cultivars of Gerek and Kutluk (1972), Sethi and Singh (1972), Kiss (1973), Saini and Nanda (1974), Abdalla et al. (1986) and of Inam (1978), Abbas et al., 1983a, Moinuddin et al. (1985), Samiullah et al. (1987) and Moinuddin et al. (1990) from our own laboratory.

After having considered the effect of treatments and cultivars separately, it is not surprising that the best interaction effect on each of the growth parameters at all stages was that of $N_{100+50}P_{60}$ x Delfin (Tables 6-10).

5.3 Leaf -N, -P and -K contents

Leaf analysis is recognised as a diagnostic tool for assessing the nutrient requirements of plants. It is widely used to study the complex interactions between plant growth and the environment (Lundegårdh, 1951). The concentration of the nutrients in the leaves can influence the rate of photosynthesis, among other processes (Terry and Ulrich, 1973a,b,c). According to Milthorpe and Moorby (1979), far reaching influences of nutrients are likely to be exerted through the number of fertile tillers produced and indirectly through the extent of leaf surface generated. This view is also shared by Gardner *et al.* (1985).

In Experiment 1, the concentration of leaf -N, -P and -K was higher at tillering in comparison with the later stages. These findings confirm the reports of Inam *et al.* (1982b), Moinuddin (1989) and Samiullah *et al.* (1991) on triticale.

The increase in nitrogen concentration at heading stage may be obviously due to the additional amount of 50 kg N/ha at tillering. It confirmed the effectiveness of top-dressing of nitrogen (Ashfaq, 1986). Increase in phosphorus and potassium concentration was also noted due to the top-dressing of nitrogen. Grunes and Krantz (1958) noted that, within limits, nitrogen, supply increases the proliferation of roots, whereas, Grunes *et al.* (1958) attributed increased absorption to an effect of nitrogen on the physiological processes that control the absorption of phosphorus. The synergistic effect of nitrogen application on phosphorus and potassium uptake is well documented (Inam et al., 1982b; Samiullah et al., 1991).

Tables 12 and 13 reveal that, at tillering stage, the concentration of nitrogen and phosphorus was more in the leaves that received 60 kg P_2O_5/ha. This might be due to the positive effect of applied phosphorus on nitrogen and phosphorus uptake and accumulation (Chahal et al., 1983). This observation is also in agreement with that of Roy and Wright (1974) who observed enhanced nitrogen uptake with increasing levels of applied phosphorus.

In general, Table 14 reveals that leaf potassium concentration was higher in treatments containing higher dose of phosphorus (P_{60}). It is noteworthy that Lundegårdh (1951) and Dev (1965), among others, have reported an increase in leaf potassium concentration due to phosphate manuring.

A noteworthy feature of Tables 12-14 is that the concentration of leaf -N, -P and -K declined with the maturity of the plants. This situation arises essentially due to an exponential increase in the growth (weight and volume) of the plants as a result of which even high quantities of nutrients appear to be less when expressed on per unit basis and is generally referred to as the " dilution with growth effect" (Moorby and Besford, 1983). Besides, translocation of nutrients to the sinks (grains), during the emergence and subsequent development of ears, could also deplete leaf nutrient content at later stages of growth.

Cultivar differences with regard to leaf nutrient concentration are apparent in Tables 12-14. Delfin showed the maximum nitrogen, phosphorus and potassium concentration at all the growth stages, followed by TL-419 and wheat in that order, while Tigre'S' came last. These genetically-controlled differences may presumably arise, as reported by Gregory and Crowther (1928), from differences in efficiency of absorption and utilisation of the nutrient constituents of the soil. Genotypes are known to differ considerably in their ability to absorb and distribute the absorbed nutrients among various parts of the plant (Vose, 1963; Epstein and Jefferies, 1964; Langer, 1966; Inam, *et al*., 1982b; Abbas *et al*., 1983a; Moinuddin, 1989).

Lastly, a perusal of Tables 48 and 49 establishes, for the first time for triticale, that leaf -N, -P and -K contents at heading and milky grain stages, are highly correlated (P=0.01) with grain yield and protein content. Thus where facilities exist for their determination these could be used to predict expected yield and, if found low corrective measures, such as foliar spray could be undertaken at heading stage itself.

Table 48. Correlation coefficient (γ) between various parameters and grain yield (Experiment 1).

Parameters	Stage	γ value
<u>Growth parameter</u>		
Shoot length	Heading	0.5163*
	Milky grain	0.4098 NS
Tiller number	Heading	0.7048**
	Milky grain	0.7154**
Leaf number	Heading	0.6660**
	Milky grain	0.4321 NS
Fresh weight	Heading	0.7056**
	Milky grain	0.7188**
Dry weight	Heading	0.5798**
	Milky grain	0.5104*
<u>Leaf NRA</u>	Heading	0.8255**
	Milky grain	0.7133**
<u>Leaf NPK content</u>		
Nitrogen	Heading	0.8350**
	Milky grain	0.7581**
Phosphorus	Heading	0.8661**
	Milky grain	0.8414**
Potassium	Heading	0.8345**
	Milky grain	0.5638**
<u>Yield parameters</u>	At harvest	
Ear number		0.7994**
Ear weight		0.5468*
Ear length		0.5487*
Spikelet number		0.7742**
Grain number		0.7768**
1,000 grain weight		0.7939**
Straw yield		0.5609*

** Significant at 0.01%
* Significant at 0.05%

N.S. - Non-significant

Table 49. Correlation coefficient (γ) between leaf nitrate reductase activity (NRA) and leaf -N, -P and -K contents and grain protein content (Experiment 1).

Parameters	Stage	γ value
<u>Leaf NRA</u>	Heading	0.6585**
	Milky grain	0.8657**
<u>Leaf -N, -P and -K content</u>		
Nitrogen	Heading	0.5939**
	Milky grain	0.6568**
Phosphorus	Heading	0.8149**
	Milky grain	0.8330**
Potassium	Heading	0.5873**
	Milky grain	0.7034**

** Significant at 0.01%

5.4 Leaf nitrate reductase activity (NRA)

Although the present study on leaf NRA is the first on triticales, those on other crops, including cereals, have revealed valuable information regarding the association of NRA with growth, development and yield (Akhtar, 1985; Ansari *et al.*, 1985; Gardner *et al.*, 1985; Khan, 1988). It is also to be noted that NRA itself is dependent upon photosynthesis (Ziesel *et al.*, 1963).

Table 11 (Experiment 1) reveals that the higher dose of applied phosphorus (P_{60}) resulted in higher leaf NRA than did the lower dose (P_{45}). It is noteworthy that addition of N_{50} by top-dressing at tillering had a very salutary effect on the activity of the enzyme estimated at heading and milky grain stages. Lastly, the data also reveal that leaf NRA decreased with the advancing age of the plants from tillering to milky grain stage (Table 11).

These results can be understood in the light of the response of NRA to the availability of N, P and K at the site of its formation and action. Thus, nitrate being the inducer as well as stabiliser of the enzyme nitrate reductase (Hewitt and Afridi, 1959; Afridi and Hewitt, 1964; Beevers and Hageman, 1980), applied nitrogen (absorbed by the roots commonly in the form of nitrate), particularly by top-dressing at the tillering stage, might have been directly responsible for the higher leaf NRA levels in top-dressed plants ($N_{100+50}P_{45}$ and $N_{100+50}P_{60}$) at heading and milky grain stages compared with NRA in $N_{100}P_{45}$ and $N_{100}P_{60}$ treated plants (Table 11).

The observed effect of nutrients on leaf NRA in the present experiment could be best understood in the light of the data on leaf -N, -P and -K considered above (Tables 12-14) which also show higher levels due to applied nitrogen and phosphorus. In contrast to the direct role of nitrogen (as nitrate), phosphorus and potassium play indirect roles. The level of inorganic phosphorus, for example, in the leaf tissues is known to be responsible for the phosphorylation and diversion of simple sugar towards respiration as a result of the release of photosynthates from the chloroplasts. Oxidation of these sugars produces more reducing power subsequently for the nitrate reductase-mediated NO_3^- reduction (Kow et al.,1982; Marschner, 1986). Similarly, potassium, being involved in peptide-bond synthesis (Webster, 1959) and in other energy releasing processes (Evans and Sorger, 1966), would be expected to enhance NRA in leaf tissues with higher K content (Table 14).

The cultivars exhibited significant differences in leaf NRA at each of the three growth stages at which leaves were sampled. Delfin gave the highest value for leaf NRA, followed by TL-419 and wheat check. Tigre'S' gave the lowest value (Table 11). This observation is obviously due to inherent differences in the capacity of the cultivars to absorb soil nitrate at various growth stages of the plant (Nataraju *et al.*, 1990). Similar cultivar differences in leaf NRA have been reported for several other cereal crops (Rao *et al.*, 1977; Nair and Abrol, 1982; Naik *et al.*, 1982; Singh and Singh, 1985).

For obvious reasons, $N_{100+50}P_{60}K_{30}$ x Delfin proved the best combination for leaf NRA both at heading and milky grain stages. However, at the tillering stage before N_{50} was added by top-dressing, $N_{100}P_{60}$ x Delfin proved superior to all other combinations.

It is pertinent to note here that, in addition to the importance of its physiological role in the nitrate metabolism, NRA has been claimed to show a reliable relationship with grain yield and quality in cereals (Croy and Hageman, 1970 in wheat; Deckard *et al.*, 1973 in Maize; Eilrich and Hageman, 1973 in wheat; Dalling and Loyn, 1977 in wheat; Nair and Abrol, 1982 in wheat). This has been extended by the present author to include triticale for the first time (Tables 48 and 49), like the leaf -N, -P and -K associated with grain yield and quality noted above.

Hence, it may be concluded that if facilities are available for the rapid assay of NRA, as employed in this study, a reliable prediction could be made at early growth stages about the yield and quality of triticale grain.

5.5 Yield characteristics

Ear emergence and grain filling are the culmination of various inter-linked physiological activities of cereals which depend upon the course of plant growth, development and differentiation. Grain yield in a crop plant would, therefore, be directly or indirectly related with various growth and yield characteristics. Being the ultimate aim of the grower, efforts to maximise grain yield by farm scientists is bound to get all round appreciation and if the quality of the grain is also improved in the process it would be an added bonus.

In the Experiment 1, the effect of the higher dose of phosphorus (P_{60}) at both nitrogen regimes (N_{100}, N_{100+50}) on all yield attributes was noted to be significantly better than that of P_{45} (Tables 15-22). These results not only corroborate the data of several fertiliser trials on other cultivars of triticale , particularly those of Kiss and Feher (1968), Andrascik and Matusov (1973), Dimitrov et al. (1982), Moinuddin et al. (1990) and Samiullah et al. (1991), but also establish the superiority of Delfin over the other cultivars of triticale as well as the wheat check.

Treatment $N_{100+50}P_{60}$ resulted in the maximum value for each of the yield attributes (ear number, ear weight, spikelet number, grain number and 1,000 grain weight). In contrast, the lowest values for yield attributes were recorded in treatment $N_{100}P_{45}$. These observations indicate the effectiveness of balanced nutrition for maximisation of yield attributes leading to high yield, as already mentioned with regard to vegetative growth (P.101).

Considering each yield attributing characteristics separately, it is clear from Table 15 that more ears were produced in $N_{100}P_{60}$ than in $N_{100}P_{45}$ as well as in $N_{100+50}P_{60}$ than in $N_{100+50}P_{45}$. This clearly establishes the involvement of phosphorus in the production of fertile tillers as noted for other triticales by Sethi and Singh (1972), Sethi et al. (1979) and Prasad and Singh (1983). Moreover, the lower values of ear numbers in N_{100} than in N_{100+50} at both P levels are a reflection of the requirement of adequate nitrogen in the presence of phosphorus for tillering in grasses (Langer, 1972) and cereals, including wheat (Fuehring, 1969).

The weight of the ear (Table 16) is a measure of partitioning of the photosynthate between the vegetative and reproductive parts of the plant. The data again show that $N_{100+50}P_{60}$ produced the heaviest ears, with $N_{100}P_{45}$ giving the lowest value, thus indicating the involvement of phosphorus in the process (Black, 1968).

In Table 17, ear length also was found to be promoted most by $N_{100+50}P_{60}$. However, $N_{100+50}P_{45}$ and $N_{100}P_{60}$, that followed it, were at par. This reminds us of the promotory role of phosphorus in cell division and expansion leading to increased vertical growth (Hewitt, 1963; Black, 1968; Patnaik, 1987) even at low nitrogen level noted earliar (P. 102). In fact, phosphorus is credited with increasing the efficiency of nitrogen for plant processes in general (Wallace, 1961).

A perusal of Table 18 and 19 also clearly establish a direct role of phosphorus in spikelet and grain number, with $N_{100+50}P_{60}$ giving the highest values and $N_{100}P_{60}$ and $N_{100+50}P_{45}$ (being at par) following it. Such an effect of basal phosphorus on promotion of spikelet production has been noted in other cereals, particularly wheat (Rahman and Wilson, 1977; Mohapatra et al., 1983) and for grain number in triticale (Prasad and Singh, 1983).

Table 20 (1,000 grain weight) shows a slight variation from the other tables of yield attributes considered so far. $N_{100+50}P_{60}$ gave the highest value for 1,000 grain weight also; but it was followed by $N_{100}P_{60}$ which differed critically with the remaining two treatments in its effect. That the treatments with higher phosphorus (P_{60}) level promoted this attribute more than those with the lower dose (P_{45}) is a clear indication of the role of phosphorus in swinging the partitioning of photosynthate towards grain filling as noted for most cereal crops (Black, 1968; Afridi and Samiullah, 1973; Qaseem et al., 1978; Giaquinta and Quebendeaux, 1980; Orphanos and Krentos, 1980).

Table 21 on grain yield shows the positive cumulative effect of the treatments on this most important characteristics. That most of the growth characteristics, leaf -N, -P and -K contents, leaf NRA at later stages and yield attributes at harvest contributed highly significantly (P=0.01) to grain yield is borne out by correlation studies (Table 48).

Not surprisingly, $N_{100+50}P_{60}$ gave the highest value and $N_{100}P_{45}$, the lowest. However, $N_{100+50}P_{45}$ was noted to out-yield $N_{100}P_{60}$. The results clearly indicate the necessity for balanced fertiliser application (note that K_{30} was also applied uniformly in all treatments). The data of the experiment under consideration confirm the findings of a very larger number of workers on wheat and other cereals (Yoshida, 1972). Similar results have also been published for triticale cultivars (Andrascik and Matusov, 1973; Reddy and Lal, 1976; Bishnoi and Hughes, 1979; Ponce _et al_., 1981; Prasad and Singh, 1983; Dimitrov, 1985; Dziamba, 1987; Moinuddin _et al_., 1990).

Lastly, in view of the best effect of $N_{100+50}P_{60}$ on all growth (Tables 6-10) andyield (Tables 15-20) attributes, it is not surprising that this treatment resulted in the highest straw yield (Table 22).

As would be expected from its all round superior performance regarding growth (Tables 6-10) and yield (Tables 15-20) attributes noted above, Delfin out-yielded not only the other three triticales but also the wheat check in the present study (Table 21). Such cultivar differences are well documented. Among the triticales, Delfin's prolific yielding ability has also been established by Moinuddin et al. (1990) from our laboratory. A noteworthy feature of this cultivar is its high straw yield in addition to high grain yield which makes it outstanding among the presently available triticales simultaneously for feed and fodder.

Not surprisingly, the combination $N_{100+50}P_{60}$ x Delfin proved best for all yield attributing characteristics (Tables 15-20) as well as for grain (Table 21) and straw (Table 22) yield. This clear-cut observation commends the adoption of Delfin to be cultivated commercially with a basal dose of $N_{100+50}P_{60}K_{30}$ in Western Uttar Pradesh, (India) where the trial was conducted.

5.6 Spray of phosphorus and growth stages

Having established the clear-cut relationship between growth and yield attributes as well as leaf nutrient content and NRA with grain yield in Experiment 1, it was considered appropriate to select Delfin, the best performing cultivar of this experiment for the next factorial randomised field trial (Experiment 2) and to confine the attention on grain yield and quality. The aim of this experiment was to test, on the basis of yield attributes and grain quality only, the efficacy of foliar spray of 4 kg P/ha applied at tillering and/or heading and/or milky grain stage in equal splits (T, H, M, TH, TM, HM and THM). The cultivaral practices of the previous trial and the wheat check (HD-2204), were retained for this experiment with the exception that only P_{45}, the sub-optimal dose of phosphorus (45 kg P_2O_5/ha) was applied to the soil together with N_{100+50} and K_{30}.

The data of this experiment (Tables 29-36) lend significant indirect support to the findings of Nicholls (1974) who reported that the inflorescence growth and development in cereals are under the control of inorganic nutrients (and hormones). The sprayed phosphorus could influence both these factors apart from having a direct effect both at the vegetative (T) and reproductive (H and M) stages. In this connection it is pertinent to mention that Mitchell (1957) noted that most of the phosphorus present in the aerial portions of wheat migrates to the heads as the plants mature. The ready availability of the sprayed phosphorus at the site of photosynthesis and translocatory activity would, therefore, ensure faster and sustained grain filling, resulting in all round enhancement in yield attributing characteristics as well as grain yield.

Considering the parameters one by one, the inclusion of tillering stage in the spray schedule (T, TH, TM or THM) had a beneficial effect on ear production, treatments H, M and HM proving at par with the control. It may be pointed out that the number of ears depends mainly on the number and fertility of tillers. The application of phosphorus at tillering in T, TH, TM and THM might have initiated new tillers as phosphorus ensures sustained meristimatic activity and growth (Tamhane *et al.*, 1970), thereby increasing indirectly the number of ears. It is, however, noteworthy that the number of ears produced in T was critically lower than that produced in TH, TM and THM (that were at par). This indicates that availability of phosphorus at the two later stages is equally necessary for sustained ear production. The separate importance of T and these two later stages is brought out by the equal effect of T and HM on ear number (Table 29). In this connection, the work of Thorne (1963) assumes considerable importance. She estimated that about 40% of the carbohydrates in the barley grain were provided by photosynthesis in the ear which led her to conclude that the contribution of ear photosynthesis to grain yield was directly proportional to the number of grains per plant.

Ear weight per plant (Table 30) is also an important yield attribute in relation to grain yield. Unlike ear number the more responsive stages to phosphorus spray for this parameters were those involving the milky grain stage (M, TM, HM and THM). This confirms that phosphorus is required not only for the formation and development of ears but also for grain filling. However, the data high light the superiority of THM over all other treatments for ear weight per plant possibly because of more fertile tillers being formed due to the early spray of phosphorus (at tillering) coupled with better grain filling due to additional sprays at the later stages.

Ear length is a measure of cell division, multiplication and elongation. According to Hewitt (1963) phosphorus is involved in these processes. The ready availability of this essential nutrient to the developing ear by repeated (two or three) sprays may, therefore, be expected to lead to longer ears than those recieving only one spray of phosphorus or water only (Table 31).

One advantage of a long ear is that it could provide more space for spikelet formation and grain production. This is brought out, clearly by a perusal of Tables 32 and 33 respectively. Treatments THM, followed by HM and TH, that were most effective in increasing ear length also resulted in enhanced spikelet number and grains per ear, evidently due to ready availability of phosphorus at the growth stages when it was needed most and could not probably be supplied in sufficient quantity by the soil.

Regarding 1,000 grain weight and grain yield, Tables 34 and 35 clearly indicate that spray of phosphorus was more beneficial if applied at the milky grain stage. Of course, two or more sprays including this stage (TM, HM and THM) gave still better results, reminding of Thorne (1958), who stated that " maximum benefits can be derived from phosphorus application during flower bud development and anthesis stage" . It is noteworthy that highest grain yield was obtained when the plants were sprayed at heading and milky grain stage (HM) or at tillering, heading and milky grain stages (THM). Treatment HM is, therefore, to be prefered on economic ground for grain production as it saves one spray operation. The data confirm the findings of Afridi and Samiullah (1973) who reported the superiority of spray of phosphorus at heading and milky grain stages for maximum grain yield of barley.

The above findings of the present author thus confirm the involvement of phosphorus at tillering stage in the formation of fertile tillers. This, coupled with further supply of the nutrient at heading and milky grain stages, leads to increase in ear length, spikelet formation, grain formation and grain filling, through improved partitioning of photosynthates for grain formation. This is very clearly borne out by the highly significant correlation (P=0.01) between these yield attributing characteristics and grain yield (Table 50).

Lastly the production of straw (Table 36) presents an interesting picture. Like ear number and ear length, spray at tillering stage proved to be indispensible for enhanced straw production (see, for example T, TH, TM and THM), thus confirming the participation of the nutrient in tiller and leaf formation and growth in addition to other activities. Spray at tillering stage seems to ensure early vegetative growth which is sustained and

Table 50. Correlation coefficient (γ) between yield characteristics and grain yield (Experiment 2).

Parameters	γ value
Ear number	0.5879*
Ear weight	0.7249**
Ear length	0.8224**
Spikelet number	0.8383**
Grain number	0.8760**
1,000 grain weight	0.8168**
Straw yield	0.6445**

** Significant at 0.01%

* Significant at 0.05%

enhanced further by the sprays at heading and milky grain stages, thereby increasing the straw weight at the time of crop maturity (Tamhane et al., 1970; Yoshida, 1972).

With regard to the two crops taken, Delfin gave better performance than the wheat check for all yield attributes. (Tables 29-36). For example, its grain yield was 22.32% higher (Table 35), confirming the results of Experiment 1. It may be noted that Delfin in general proved superior to the other cultivars of triticale as well as wheat in that experiment with regard to growth parameters like leaf number, tiller number and plant height etc. This inherent quality of Delfin must have played a decisive role to give it an edge over the wheat check by providing a larger surface area for the efficient absorption and translocation of the sprayed nutrient. It seems this improved cultivar of triticale is also able to utilise the sprayed phosphorus better than wheat for formation of more (Table 29), heavier (Table 30) and longer ears (Table 31) with more spikelets (Table 32) and grain (Table 33), which were heavier (Table 34) and thus contributed to better yields (Tables 35 and 36).

When we consider the effect of various T x Cv interactions, which were significant, it becomes evident that each treatment proved better for Delfin than for wheat (Tables 29-36). To cite the example of the most important characteristics, i.e. grain yield, it is revealed by Table 35 that HM x Delfin and

THM x Delfin (which were at par) resulted in more than 23% higher grain yield than HM x wheat and THM x wheat. Even water x Delfin proved 19.35% better than water x wheat and this is true more or less for all other comparable interactions. Lastly, a measure of the effect of phosphorus spray is afforded by considering THM x Delfin or THM x wheat which produced 30.62% and 26.50% more grain than water x Delfin or water x wheat respectively.

5.7 Efficacy of phosphorus sources

While testing the efficacy of three common sources of phosphatic fertiliser in increasing triticale yield in the last simple randomised field trial (Experiment 3), monocalcium superphosphate proved the best source of phosphorus. These results are in conformity with those of earlier workers including Gupta *et al*. (1972) in Maize; Sethi *et al*. (1979) in triticale and Mishra *et al*. (1980) in wheat. Incidently, the data also confirmed the results of Experiment 2 regarding the general efficacy of foliar application of phosphorus over the water-sprayed control (Table 43).

The higher efficiency of monocalcium superphosphate seems to be due to its ability to supply phosphorus in the form of $H_2PO_4^-$ which is taken up more readily than HPO_4^{--} released from diammonium phosphate (Hagen and Hopkins, 1955). Interestingly, sodium dihydrogen orthophosphate, also provides phosphorus in $H_2PO_4^-$ form but did not give as good results as monocalcium superphosphate. It may be due to the fact that the sulphur, present as an impurity in the latter (Black, 1968) also become available to the plants at critical stages of growth and is incorporated readily into proteins and enzymes, resulting in superior performance of the crop. The findings of Sacchidanand _et al_. (1980) give additional support to results obtained in the present study. They reported better utilisation of spray of monocalcium superphosphate than of DAP for dry matter production and 100 seed weight as well as grain and straw yield of the crop. Sulphur, besides increasing phosphorus availability (Upadhyay _et al_., 1988) also enhances the assimilation rate, ultimately leading to higher grain yield.

Considering the effect of applied sources on individual yield attributing characteristics (Table 43), it is noteworthy that commercial grade monocalcium superphosphate increased all parameters including grain yield most. Diammonium phosphate (DAP) generally followed it and was even at par with it for ear length, 1,000 grain weight and straw yield. Sodium dihydrogen orthophosphate gave the lowest values for ear weight and 1,000 grain weight, while it was at par with DAP in its effect on ear number and length, spikelet and grain number and grain and straw yield. Correlation studies to determine the degree of association of the yield attributing parameters with grain yield were formed to be significant in this trial also (Table 51).

Table 51. Correlation coefficient (γ) between yield characteristics and grain yield (Experiment 3).

Parameters	γ value
Ear number	0.8843^{*}
Ear weight	0.8714^{*}
Ear length	0.7087^{*}
Spikelet number	0.8532^{*}
Grain number	0.9557^{**}
1,000 grain weight	0.8025^{*}
Straw yield	$0.3569^{N.S.}$

** Significant at 0.01%

* Significant at 0.05%

N.S. Non-significant.

It may, therefore, be concluded that triticale cultivar Delfin may be cultivated profitably with a sub-optimal phosphorus dose of 45 kg P_2O_5/ha together with 100 kg N and 30 kg K/ha applied at sowing and 50 kg N/ha added as top-dressing provided 4 kg P/ha is sprayed in two equal splits at heading and milky grain stages as Monocalcium superphosphate. Being easily available to the farmer, there should be no hesitation on his part to adopt this simple agro-technique in view of the saving of phosphatic fertiliser coupled with enhanced grain and fodder yield.

5.8 Grain quality

Cereals provide about 70-80% of the total calories and more than two thirds of the protein in human diet (Hulse and Spurgeon, 1974). As such, not only the grain yield but also the protein and carbohydrate content of the grain assume equal importance.

In Experiment 1, treatment $N_{100+50}P_{60}$ proved best for soluble, insoluble and total protein. Interestingly, $N_{100+50}P_{60}$ and $N_{100}P_{60}$ were equal in their effect as far as soluble protein was concerned while for insoluble and total protein treatment $N_{100}P_{60}$, that followed $N_{100+50}P_{60}$, proved better than $N_{100+50}P_{45}$. This observation establishes the critical importance of application of sufficient amounts of phosphorus with basal nitrogen rather than simply additing more nitrogen through top-dressing, to ensure high grain protein content. Results similar to these have been reported by some of the earlier workers on cereals including Eck et al. (1963) and Afridi and Samiullah (1973). The increase in grain protein content as a result of application of the higher dose of basal phosphorus (P_{60}) may be due to its indirect effect at the same level of applied N (N_{100} or N_{100+50}) as it might have increased the uptake of nitrogen as reported by Roy and Wright (1974) for sorghum. This assumption is supported by the high leaf -N, -P and -K contents in treatments containing P_{60} and by the highly significant ($P=0.01$) r values between the nutrient status of plants at heading and milky grain stages and grain protein content (Table 49). Although nitrogen is the chief constituents of proteins, phosphorus is involved in protein synthesis via the supply of energy-rich ATP (Hewitt, 1963) which explains the data presented in Tables 23-25.

The other important component of the grain i.e. carbohydrate, was also significantly affected by the treatments. $N_{100+50}P_{60}$ proved best for soluble, insoluble and total carbohydrate. Tables 26-28 present a picture similar to Tables 23-25 for various components of grain protein, exhibiting higher values for treatment $N_{100}P_{60}$ than $N_{100+50}P_{45}$ and $N_{100}P_{45}$, highlighting nitrogen and phosphorus while in the other treatment the importance of phosphorus through its role in energy-rich ATP and NADP, which are involved in the conduction of carbohydrates to the grains.

Among the cultivars tested, Delfin proved inherently superior to all other triticales as well as the wheat check for all fractions of grain protein and carbohydrate (Tables 23-28). Viewed in the light of the superior performance of this cultivar regarding vegetative growth and nutrient accumulation noted earlier, these observations are not surprising.

Another, interesting indication of the data on protein fractions of grain is the overall superiority of all triticale cultivars over the wheat check (Tables 23-25). This is in conformity with the findings of several workers, including Villegas (1973), Hulse and Spurgeon (1974), Kalra and Dhiman (1979), Fencik _et al_. (1980), Kolevs and Khristove (1983), Vaulina (1987), Moinuddin (1989), Moinuddin _et al_. (1990) and Samiullah _et al_. (1991), apparently because of the rye genome (Unrau and Jenkins, 1964).

In the light of the above observations on grain quality characteristics as affected by basal phosphorus application and cultivars, the interaction effects on these attributes were noted to be on predictable lines. Thus, $N_{100+50}P_{60}$ x Delfin proved the best combination for all quality characteristics with $N_{100}P_{60}$ x Delfin either at par with it or following it very closely, which again speaks for the requirement of adequate phosphorus for the maintenance of good quality cereals grain.

In Experiment 2 also, the data confirmed that there is a close relationship between ensured and continued availability of phosphorus and the quality of grain produced as significant effect of spray phosphorus applied at different growth stages was noted. Tables 37-42 reveal that, in general, three sprays (THM), followed closely by two at heading and milky grain stage (HM) gave the highest values, except for soluble and total carbohydrates (Tables 40 and 42) for which HM proved best. This probably accounts for the equal effect of HM and THM on grain yield (Table 35) noted earlier as the bulk of the grain is made up of carbohydrates. It may be added that two sprays of phosphorus (TH and TM) followed HM rather closely in their effect and that, among single spray treatments, application at milky grain stage (M) surpassed the others (T and H). These results highlight the effectiveness of the foliar application of phosphorus at later growth stages (THM, HM, TH, TM and M) for ensuring good quality grains. Similar results have been reported for wheat and barley, including those from our own laboratory (Qaseem, 1975; Qaseem *et al*., 1978).

In Experiment 3 also spray of phosphorus affected grain protein as well as carbohydrate significantly, with monocalcium superphosphate giving the best results (Table 44).

The application of phosphorus is known generally to decrease the grain protein concentration in cereals (Dreyspring *et al*., 1931; Mukherji and Agarwal, 1944; Atkins *et al*., 1955;

Eck *et al.*, 1963; Singh and Gupta, 1969). Samiullah and Afridi (1975) also reported a similar depressing effect of both soil-applied and leaf-applied phosphorus on grain protein content of barley. However, it may be pointed out that these studies were done with basal dressing of nitrogen and no top-dressing was applied. It is possible that nitrogen losses from the soil (Anonymous, 1971) rendered the plants deficient in this essential nutrient at later stages of growth which could account for low protein content. However, in all the three experiments comprising the present study, nitrogen was added in two splits (at sowing and tillering) which would be expected to maintain its concentration in the plant tissues at later stages of growth. As a result, in the presence of adequate quantities of phosphorus applied basally or by supplemental foliar spray, high protein content of grain was ensured.

Lastly, Table 44 also shows that spray of monocalcium superphate enhanced various fractions of grain carbohydrate more than that of the other two sources of phosphorus, supporting the findings of Sharma *et al.* (1971) and explaining the author's data on grain yield (Table 43) in this experiment as well as in the earlier experiment (Table 35), as carbohydrates contribute the major constituents of the cereal grain.

5.9 Milling and baking

From the inception of this crop in the late 19th century, the abnormal endosperm development with shrivelled grain had been a persistent problem in the improvement of triticale. This was reflected in lower test weight in many studies (Unrau and Jenkins, 1964; Hulse and Spurgeon, 1974; Brower, 1977). It resulted in low flour extraction compared to wheats. However, it is heartening to note that the newly released cultivars of triticale show a significant improvement in terms of better test weight thereby matching the flour content of wheat (Anonymous, 1979). In the present study the triticale cultivar Delfin was very close in terms of flour extraction with that of wheat cultivar HD-2204 with a difference of only 5%.

Wheat is one of the most popular cereals in the human diet because of its versatility and quality. In addition the protein of wheat has unique physiochemical properties due to its cohesive rubbery mass called gluten. The gluten made from bread-wheat flour developes into a dough that is strong and elastic, it can be streched and inflated without tearing or breaking, a property much needed in chapatti making. When the dough is baked, the gluten coagulates and the starch gelatinises to yield the crust covered material we known as bread (Hulse and Spurgeon, 1974).

In the present study the baking quality of three samples of flours were evaluated visually as well as by sensory testing. It was found that the blend of triticale and wheat flour produced the buns and chapatti equal to wheat in acceptability. These results confirm earlier findings (Tsen et al., 1973; Berova, 1974; Saurer and Dormann, 1974; Chawla and Kapoor, 1983). Improvement in quality of triticale with the addition of wheat flour (50%+50%) may be due to the gluten of wheat flour which may be responsible for the better quality of blended flour, because gluten is supposed to be the major factor controlling the dough strength and bread of chapatti making quality (Hulse and Spurgeon, 1974; Anonymous, 1984; Anonymous, 1986).

Softness of the buns was not distinct, except in 100% wheat and 100% triticale flour. When the blend was taken into account it was at par with 100% wheat on the one hand and 100% triticale on the other, presumably due to the presence of gluten of wheat in the blend which was lower in the 100% triticale flour.

Regarding the softness of chapatti of the three flour samples (Table 45) no-significant difference was noted. Similar observation have been reported earlier (Anonymous, 1976b; Saurer and Dormann, 1979). The broken edges in triticale chapattis may be due to its lower gluten content which is an important technological limitations with triticale since it is supposed to be partly responsible for the weakness of dough. The blend of the two flours (wheat + triticale) shows an improvement as its chapatti margins were noted to be less broken due to the presence of wheat protein gluten and the dough strength (Unrau and Jenkins, 1964; Anonymous, 1986).

It is interesting to note that the colour of the buns was almost similar in all the three samples indicating the acceptability of the loaf for commercial purpose (Plate 4).

However, when the colour of the chapattis is taken into account, it may be observed that wheat flour chapattis were more acceptable than those of triticale, while the blend of the two flours was matching with wheat (Plate 5).

5.10 Conclusion

From the present study the following points may be drawn :

(1) Triticale could be grown commercially under the agro-climatic conditions of Aligarh, Western Uttar Pradesh (India) as its cultivar Delfin out-yielded to locally popular high-yielding cultivar of wheat (HD-2204) in all respects, including grain yield and quality.

(2) The higher dose of phosphorus (P_{60}) proved adequate with top-dressing of 50 kg N/ha at tillering.

(3) Supplemental spray of phosphorus applied in treatments including the tillering stage proved very effective for vegetative growth as well as straw yield, whereas application at heading and milky grain stages proved

best for grain yield and quality of plants grown with a sub-optimal dose phosphorus plus adequate nitrogen and potassium applied to the soil. Two sprays at heading and milky grain stages proved as effective spray at all three stages, resulting in some saving in the cost of fertiliser and labour.

(4) For the purpose of foliar spray the monocalcium superphosphate proved economical in comparison with DAP and NaH_2PO_4.

(5) Flour yield of triticale cv. Delfin was close to wheat check with only a difference of only 5%.

(6) Baking quality of blended flour of triticale and wheat in 1:1 ratio gave the acceptable quality (softness, colour and flavour) of buns and chapatti.

CHAPTER 6

SUMMARY

SUMMARY

The thesis comprises six chapters.

Chapter 1 (Introduction) deals with the need of mineral nutrition studies with regard to growth and yield and the importance of triticale as a new commercial cereal crop. The selection of the problem regarding the phosphorus nutrition of triticale has been critically considered and the proposed field trial explained.

Chapter 2 (Review of Literature) includes a brief review ofthe available published work regarding the brief history and origin of triticale, role of phosphorus in plant nutrition, and its requirement for growth, yield, grain quality, foliar nutrition and milling and baking qualities of triticale.

Chapter 3 (Materials and Methods) contains the details of the cultivars and the methodology employed for the three field trials planned according to standard statistical designs. The procedure for evaluation of milling and baking quality is also given.

Chapter 4 (Experimental Results) comprises the important data analysed statistically. These are summarised in Tables 6-46 and are briefly described below:

Experiment 1 (1988-89): The aim of this factorial randomised field experiment was to test the comparative performance of four newly released cultivars of triticale (Delfin, Driera, TL-419 and Tigre'S'), keeping a locally popular high yielding dwarf cultivar of wheat (HD-2204) as check, under two levels of basal phosphorus i.e. 45 and 60 kg P_2O_5/ha (P_{45} and P_{60}) with a uniform basal dose of potassium 30 kg K/ha. In addition, 100 kg N/ha was given at sowing and another 50 kg N/ha was top-dressing at tillering stage. Thus, in all, there were four treatments $N_{100}P_{45}K_{30}$, $N_{100}P_{60}K_{30}$, $N_{100+50}P_{45}K_{30}$ and $N_{100+50}P_{60}K_{30}$. Seeding rate was 100 kg seed/ha. The performance of the cultivars was assessed on the basis of growth parameters, leaf NRA and -N, -P and -K contents, yield characteristics and grain quality.

Growth characteristics of the cultivars were significantly enhanced by the higher dose of phosphorus (P_{60}) under both regimes of nitrogen i.e. N_{100} and N_{100+50} at the three stages. Delfin gave the best performance, wheat occupied a middle position and Tigre'S' gave the poorest performance. $N_{100+50}P_{60}K_{30}$ x Delfin proved the best combination for all the growth parameters.

Leaf NRA and -N, -P and -K contents were significantly enhanced by the treatments. The higher dose of phosphorus (P_{60}) proved better. The effect was highlighted by the top-dressing with nitrogen at heading and milky grain stages.

The leaf NRA and -N, -P and -K contents decreased with the maturity of the crop. Maximum leaf NRA and -N, -P and -K contents were noted in Delfin. $N_{100+50}P_{60}K_{30}$ x Delfin proved the best combination for leaf nitrate reductase activity as well as leaf -N, -P and -K contents at heading and milky grain stages, while at tillering $N_{100}P_{60}$ x Delfin proved best.

Yield characteristics were also significantly affected by the fertiliser treatments. Like the growth parameters, yield characteristics were enhanced by the higher dose of phosphorus, particularly after the addition of nitrogen by top-dressing. Among cultivars, Delfin gave the best performance for all the yield attributes, including grain yield. In grain production, it out-yielded even the wheat check. Tigre'S' gave the poorest performance.

Quality characteristics comprising various fractions of protein and carbohydrate contents of grain, showed the same pattern as the other parameters noted above. Thus, treatment $N_{100+50}P_{60}K_{30}$ gave the highest value for grain protein and carbohydrate contents.

Delfin again proved the best cultivar for grain quality. Wheat gave the poorest grain protein content, although it closely followed Delfin in carbohydrate content. Among interaction effects, $N_{100+50}P_{60}$ x Delfin proved the best and $N_{100}P_{45}$ x wheat, the poorest combination for grain quality.

Experiment 2 (1989-90): The aim of this factorial randomised experiment, based on the data of Experiment 1, was to findout the best stage(s) for the spray of supplemental phosphorus applied on, Delfin grown with a starter basal dose of $N_{100+50}P_{45}K_{30}$. The response was compared on the basis of yield and grain quality. For comparison wheat cultivar HD-2204 was retained as check. The quantity of phosphorus applied in the form of monocalcium superphosphate sprayed as 0.2% solution was 4 kg P/ha. The spray was applied either once at tillering (T), heading (H) or milky grain (M) stage or in two equal splits at tillering + heading (TH), tillering + milky grain (TM) or heading + milky grain (HM) stages or in three equal splits at tillering + heading + milky grain (THM) stages. The control was sprayed with de-ionised water. The seed rate was 100 kg/ha.

The spray of phosphorus at all three stages (THM) proved best for most yield attributes and quality characteristics of grain. For grain yield, however, THM was at par with HM. It was also noted that, spray at two stages (TH, TM or HM) proved more beneficial than single spray (T, H or M). Delfin again out-yielded the wheat check in grain yield as well as grain protein and carbohydrate contents.

Experiment 3 (1990-91): The aim of this simple randomised block design experiment was to confirm the findings of Experiment 2 on triticale cultivar Delfin. In addition to foliar application of monocalcium superphosphate, two other sources of phosphorus, namely sodium dihydrogen orthophosphate and diammonium phosphate were taken as spray treatments in view of their lower cost and easy availability to the farmers. 4 kg P/ha in the form of 0.2% aqueous solution was applied in 2 equal splits (while the control was sprayed with de-ionised water) at heading and milky grain stages (HM) that proved optimum in Experiment 2. A uniform starter dose of $N_{100+50}P_{45}K_{30}$ was applied at sowing. Only 40 kg seed/ha was sown by dibbling method to ensure a good stand.

Spray of monocalcium superphosphate gave the best results for all yield parameters and for grain protein and carbohydrate contents.

Milling and Baking quality : The milling and baking quality of the grain of triticale cultivar Delfin was tested. The comparison was made with wheat check (HD-2204). Although, the grains of Delfin produced 5% less flour in comparison with wheat, a 1:1 blend (wheat:Delfin flour) gave acceptable colour, shape and taste of bun and chapatti.

Chapter 5 (Discussion) includes consideration of the experimental results and their correlations (Tables 47-51) in the light of research work of other scientists on cereal crops in general and triticale in particular.

Chapter 6 (Summary) i.e. the present chapter, gives the gist of the entire study and is followed by an up-to-date bibliography, comprising the references cited in the text.

REFERENCES

Abbas, Z. 1980. "Mineral Nutrition of Some New Varieties of Triticale". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Abbas, Z.; Samiullah; Afridi, M.M.R.K.; Inam, A. and Ashfaq , N. 1983a. Response of triticale varieties to varying plant densities, yield components and yield. Acta Botanica Indica, 11 : 83-85.

Abbas, Z.; Samiullah; Afridi, M.M.R.K.; Inam, A. and Ashfaq , N. 1983b. Physiomorphological studies of eight new triticale varieties. Geobios, 10 : 263-266.

Abdalla, O.S.; Varughese, G.; Saari, E.E. and Braun 1986. Spring Triticale : names; parentage; pedigrees; origins; CIMMYT (Mexico).

Acosta, A. 1973. Table 1. In : Results of the second and third International Triticale Yield Nurseries, 1970-71, 1971-72. Information Bulletin No. 10, CIMMYT, Mexico.

Afridi, M.M.R.K. 1983. Foliar fertilisation and crop productivity. National Symposium on Plant Nutrition (Abst.), Lucknow University, Lucknow.

Afridi, M.M.R.K. and Hewitt, E.J. 1964. "The inducible formation and stability of nitrate reductase in higher plants. I. Effects of nitrate and molybdenum on enzyme activity in cauliflower". 1. Exp. Bot., 15 : 251-271.

Afridi, M.M.R.K.; Naqvi, A. and Samiullah 1978a. Effect of phosphorus spray on the seed quality of mustard. In : "Physiology of Sexual Reproduction in Flowering Plants" 1976, C.P. Malik et al., Eds., pp. 258-261: Kalyani Publishers, New Delhi.

Afridi, M.M.R.K.; Parvaiz, M.A. and Samiullah 1983. Cumulative role of basal and foliar fertilisation in enhancing the yield of Laha-101. J. Indian bot. Soc., 62 : 68-72.

Afridi, M.M.R.K. and Samiullah 1973. A comparative study of soil and leaf applied phosphorus on the yield of barley (*Hordeum vulgare*). New Phytol., 72 : 113-116.

Afridi, M.M.R.K.; Samiullah; Inam, A. and Ashfaq N. 1977. Effect of nitrogen on the yield of wheat and triticale (Abst.). Acta Botanica Indica, 5 : 24.

Afridi, M.M.R.K.; Samiullah and Qaseem, S.M. 1978b. On the improvement of grain quality in wheat by foliar fertilisation. In : "Physiology of Sexual Reproduction in Flowering Plants", 1976. C.P. Malik et al., eds., pp. 226-270. Kalyani Publishers, New Delhi.

Afridi, M.M.R.K. and Wasiuddin 1979. Foliar fertilisation of crop plants. A review. In : "Recent Researches in Plant Sciences". S.S. Bir, ed. pp. 390-394. Kalyani Publishers, New Delhi.

Agarwal, J.P. 1977. Response of triticale varieties to nitrogen. Indian J. Agron. 22 : 112.

Agarwal, J.P. 1979. Relative performance of triticale varieties to nitrogen in Kabar soil of Bundelkhand. Indian J. Agron. 24 : 24-26.

Akhtar, M. 1985. "Mineral Nutrition of Moong and Lentil". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Akhtar, M.; Samiullah; Afridi, M.M.R.K. and Ansari, S.A. 1984. Effect of leaf applied N and P at two basal fertiliser levels on the yield of lentil. J. Indian bot. Soc., 63 : 91-96.

Ali, M. and Rajput, P.R. 1978. A note on studies on nitrogen requirement of triticale under rainfed conditions. Annals of Arid Zone, 17 : 229-232.

Alvi, M.S. 1984. "Studies on The effect of Mineral Nutrients on the yield and the Grain Quality of triticale". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Anand, S.C. 1972. Table 28. In : Results of the First International Triticale yield Nursery, 1969-70. Information Bulletin No. 1, CIMMYT, Mexico.

Andraščik, M. and Ličko, J. 1977. Reactivity of several species and varieties of winter cereals on gradually increased rates of nutrients under the ecological conditions of the potato producing area. Polnohos podárstvo, 23 : 665-675 (Cited from Triticale Abstr., 5 : 143).

Andrašćik, M. and Matušov, J. 1973. A study of the effect of synthetic fertilisers on the yield of the winter wheat and triticale in the potato growing area. Polnohas Podarstvo., 18 : 1043-1054 (Cited from field crop Abstr., 26 : 5402).

Anonymous, 1971. "Handbook of Manures and Fertilizers". pp. 195-210. Indian Council of Agricultural Research, New Delhi.

Anonymous, 1972. Triticale - CIMMYT Annual Report on Maize and Wheat Improvement, p. 32.

Anonymous, 1975. Triticale, Table 1,6. D. In : CIMMYT Report on Wheat Improvement, p.

Anonymous, 1976a. Triticale. In : CIMMYT Review, pp. 61-64, Mexico.

Anonymous, 1976b. Triticale. In : CIMMYT Report on Wheat Improvement, p. 51, Mexico.

Anonymous, 1977. Triticale. In : CIMMYT Report on Wheat Improvement, p. 53. Mexico.

Anonymous, 1978a. Triticale. In : CIMMYT Review, pp. 76-83, Mexico.

Anonymous, 1978b. CIMMYT Quality Laboratory. In : CIMMYT Report on Wheat Improvement, pp. 135-138.

Anonymous, 1979. Triticale. In : CIMMYT Report on Wheat Improvement, pp. 51-60, Mexico.

Anonymous 1980. Triticale. In : CIMMYT Review. pp. 59-62. Mexico.

Anonymous, 1982. Triticale, In : CIMMYT Review, pp. 71-76, Mexico.

Anonymous, 1986. CIMMYT Annual Report 1987. p. 32, Mexico.

Ansari, S.A.; Samiullah and Afridi, M.M.R.K. 1985. Predicting seed yield and protein content by leaf NRA estimation in pyridoxine-sprayed mungbean (Vigna radiata L. Wilczek) cv. K-851, Plant Physiol., 77 (Suppl) : 10.

Ashfaq , N. 1986. "Study of some Problems of the Mineral Nutrition of Triticale", Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Ashfaq , N.; Afridi, M.M.R.K.; Samiullah and Inam, A. 1984. On optimising triticale yield by judicious application of nitrogen. Indian J. Plant Nutrition. 3 : 209-213.

Atkins, R.E.; Stanford, G. and Dumenil, L. 1955. Effect of nitrogen and phosphorus fertiliser on yield and malting quality of barley. J. Agri. Fd. Chem. 3 : 609-615.

Aquilina, M. 1987. The effect of nitrogen of triticale quality. Aspects of Applied Biology. No. 15 : 293-296. (Cited from Wheat, Barley and Triticale Abstr., 5).

Austin, A. and Miri, R.K. 1961. Effect of nitrogen and irrigation on the protein and gluten content of some new Pusa Wheats. Indian J. Plant Physiol., 4 : 150.

Aziz, O. 1991. "Effect of Treated Oil Refinery Waste Water on Physiomorphological Characteristics of triticale". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Baier, A.C. 1991. Triticale in the warmer areas : Is its efficiency in nutrient uptake enough to bring farmer acceptance ? A Proceedings of the International Conference July 29 - Aug. 3, 1990. pp. 390-399. Edited, D.A. Saunders.

Bakhshi, A.K.; Sekhon, K.S.; Sandha, G.S. and Gill, K.S. 1979. Baking performance of triticale as affected by location and irrigation. J. Res., Punjab Agric. Univ., 16 : 379-384. (Cited from Triticale Abstr. 8 : 52).

Bali, A.S.; Shah, M.H.; Lahori, J.L.; Singh, K.N.; Khanday, B.A. and Koul, R.N. 1991. Studies on the production efficiency and economics of N fertilisation for wheat and triticale genotypes under Kashmir valley conditions. Fertiliser Marketing News 22 : 11-13 (Cited from Wheat, Barley and Triticale Abst. 9).

Beevers, L. and Hageman, R.H. 1980. Nitrate and nitrite reduction (Cited from Noggle, G.R., and Fritz, G.J. 1986. "Introductory Plant Physiology" II eds. p.282. Printice-Hall of India, Private Ltd. New Delhi.

Berova, S. 1974. Tests of wheat and triticale flour mixture. Rasteniev"dni Nauki 11 : 10-17 (Cited from Triticale Abst. 1 : 165).

Bhaid, S.U.; Srivastava, K.N.; Naik, M.S. and Dass, N.B. 1969. Effect of nitrogen fertilisation on protein, lysine and tryptophan contents of Indian and Mexican wheat varieties. J. Post grad. School 6 : 143-147, IARI, New Delhi.

Bhardwaj, S.D.; Agarwal, J.P. 1978. Note on the effect of nitrogen fertilization on growth and yield in different varieties of wheat and triticale. Indian J. Agric. Research. 12 : 205-206.

Bishnoi, U.R. and Hughes, J.L. 1979. Agronomic performance and protein content of fall-planted triticale, wheat and rye. Agron. J., 71 : 359-360. (Cited from Triticale Abstr., 6 : 75).

Bishnoi, U.R.; and Mugwira, L.M. 1980. Effect of nitrogen rates and sources on agronomic performance of spring triticale. Communications in soil sci. and Plant Analysis. 11 : 873-879 (Cited from Triticale Abstr. 7 : 139).

Black, C.A. 1968. "Soil Plant Relationships", II ed. John Wiley and Sons Inc., New York.

Bould, C. 1963. Mineral nutrition of plants in soils. In : "Plant Physiology - A Treatise", vol. III, F.C. Steward, ed., pp. 16-19. Academic Press, New York.

Boynton, D. 1954. Nutrition by foliar application. Ann. Rev. Plant Physiol. 5 : 31-34.

Brilhante, S.J.C.F. and Baptista, M.J.B.R.U. 1982. Some chemical and technological characteristics of triticales being bread at present. Melhoramento, 27 : 365-379. (Cited from Triticale Abstr. 9 : 322).

Bunting, A.H. and Drennan, D.S.H. 1966. Some aspects of the morphology and physiology of cereals in the vegetative phase. In : "The Growth of Cereals and Grasses", Milthorpe, F.L. and Ivins, J.D. eds., pp. 20-30. Butterworth and Co., Publ., Ltd. London.

Busch, R.H. and Wilkins, H.D. 1972. Agronomic performance of triticale in North Dakota. North Dakota Farm Res. 29 : 29. (Cited from Food Technology, 66-74, Nov. 1972).

Bushuk, W. 1980. Triticale chemistry and technology. Hodonela Roslin, Aklimatyzacja i Nosuenniclwo, 24 : 603-613 (Cited from Triticale Abstr., 9 : 82).

Brouwer, J.B. 1977. Triticale : an alternative grain crop. J. Agric. Victoria, 75 : 310-313.

Chahal, R.S., Singh, S. and Singh, M. 1983. Nitrogen, phosphorus and potassium uptake in groundnut at various stages of plant growth and levels of phosphorus. Indian J. Plant Physiol., 26 :222-225.

Chauhan, K.P.S. and Bajpai, G.C. 1972. Preliminary data on the yield performance of hexaploid triticales at high altitudes in the Kumaon hills. Current Sci., 41 : 852-853.

Chawla, V.K. and Kapoor, A.C. 1983. Acceptability of wheat triticale chapatis. Indian J. Agric. Sci., 53 : 207-211.

Cherginets, B.I.; Ryadchikov, V.G.; and Pavlov, A.N. 1980. The mineral nutrition conditions and formations of triticale grain quality. Information 3. Biological value of protein. Agrokhimiya No. 5 : 61-65 (Cited from Triticale Abstr., 8 : 61).

Croy, L.I. and Hageman, R.H. 1970. Relationship of NR activity to grain protein in wheat. Crop Sci., 10 : 280-285.

Dalling, M.J. and Loyn, R.H. 1977. Level of activity of nitrate reductase at the seedling stage as a predictor of grain nitrogen yield in wheat. Aust. J. Agric. Res., 23 : 1-4.

Deckard, E.L.; Lambert, R.J. and Hageman, R.H. 1973. Nitrate reductase activity in corn leaves as related to yields of grain and grain protein. Crop Sci., 13 : 343-350.

Dev, G. 1965. Studies on the influence of nitrogen or phosphorus application on the composition and nutrient uptake of wheat plant. Agrochimica, 9 : 80-89.

Dhiman, S.D. and Kalra, G.S. 1977. Soil moisture uptake pattern by triticale and wheat fertilized with nitrogen under rainfed conditions. Indian J. Agric. Res. 11 : 229-234.

Dimitrov, D.G., Gvozdiev, K. and Georgiev, S. 1982. Investigation of cultivation techniques for triticale. Rasteniev'dni Nauki., 19 : 88-96 (Cited from Triticale Abstr., 9 : (157).

Dimitrov, S. 1984. Study of protein and lysine content in triticale grain depending on conditions of growing. Rasteniev'd Nauki, 21 : 99-105. (Cited from Bio. Abstr. 79 : 100968).

Dimitrov, S. 1985. Influence of decreasing doses of mineral fertilisation upon the triticale productivity. Rasteniev'd Nauki, 22 : 62-66. (Cited from Bio. Abstr. 81 : 81).

Dreyspring, C.; Kurth, H. and Heinrich, F. 1931. The influence of phosphatic manuring on the yield and quality of barley. Z. Pfl. Dung., 1013 : 217. (Cited from Mukherji, B.K. and Agarwal, R.R. 1944, Indian J. Agric. Sci., 14 : 109-116).

Dubois, M.; Gills, K.A.; Hamilton, J.K.; Robers, P.A. and Smith, F. 1956. Colorimetric method for determination of sugars and related substances. Anals. Chem., 28 : 350.

Dziamba, S. 1987. Effect of CCC and fertilizer application on yield, yield components, protein and lysine contents in the grain of triticale, rye and wheat. Biuletyn Instytutu Hodowli i Aklimatyzacji Roslin No. 161, 105-112 (Cited from Wheat, Barley and Triticale Abstr.5:5050).

Eck, H.V.; Tucker, B.B. and Schlehuber, A.M. 1963. Influence of fertiliser treatments on yield, grain protein and heading dates of five wheat varieties. Agron. J. 55 : 556-558.

Eilrich, G.L. and Hageman, R.H. 1973. Nitrate reductase activity and its relationship to accumulation of vegetative and grain nitrogen in wheat. Crop Sci., 13 : 59-65.

Epstein, E. and Jefferies, R.L. 1964. The genetic basis of selective ion transport in plants. Ann. Rev. Plant Physiol., 15 : 169-181.

Etcheverse, J.D. and Moraghan, J.T. 1978. The influence of CCC and nitrogen on the yield and performance of wheat and triticale. Agro. Sur. 6 : 90-96 (Cited from Triticale Abstr. 7 : 20).

Evans, H.J. and Sorger, G.J. 1966. "Role of mineral elements with emphasis on the univalent cations". Ann. Rev. Plant Physiol, 17 : 47-76.

Farnworth, J. and Said, S.A. 1982. The effect of nitrogen on 'Beagle' triticale. Publication, Dhamar Agricultural Improvement Centre No. 50:3 (Cited from Wheat, Barley and Triticale Abstr. 1 : 2014).

Fencik, R.; Čaputa, F. and Paszko, J. 1980. Comparison of triticale and winter wheat from the view point of grain yield and the accumulation and distribution of nitrogen in the main protein fractions. Obilniny a Strukoviny, 17, 117-127 (Cited from Triticale Abstr. 9(2) : 151).

Fiske, C.H. and Subba Row, Y. 1925. The colorimetric determination of phosphorus. J. Biol. Chem., 66 : 375-400.

Fodor, J. 1974. Effect of application of nitrogen on yield and composition of some winter fodder mixtures. Takarmanybazis. 14 : 27-36 (Cited from Triticale Abstr. 4 : 21).

Fuehring, H.D. 1969. Agron. J., 61 : 591-594, (cited from Gardner et al 1985).

Gajardo B.R.P.; Parodi D.P.C. and Nebreda M.I.M. 1981. Association between leaf area, yield components and yield in wheat and triticale at different nitrogen rates. Ciencia e Investigation Agraria 8(3) : 183-195 (Cited from Triticale Abstr. 9: 62).

Gajardo, R.P.; Parodi, P.C. and Nebreda, I.M. 1978. Triticale and wheat response to nitrogen fertilizer. Agronomy Abstr. 95 (Cited from Triticale Abstr., 5 : 209).

Gardner, P.F.; Pearce, R.B. and Mitchell, L.R. 1985. "Physiology of Crop Plants". Iowa State University Press, Amer.

Gerek, R. and Kutluk, H. 1972. Table 18. In : Results of First International Triticale yield Nursery. 1969-70. Information Bulletin No. 1, CIMMYT, Mexico.

Gericke, W.F. 1922. Difference effected in the protein content of grain by applications of nitrogen made it different growing periods of the plants. Soil Sci., 14 : 103.

Giaquinta, R.T. and Quebedeaux, B. 1980. Phosphate induced changes in assimilate partitioning in soyabean leaves during pod filling. Plant Physiol. (Suppl.) 65 : 119.

Graham, R.D.; Geytenbeek, P.E. and Redcliffe, B.C. 1983. Response of triticale, wheat, rye and barley to nitrogen fertilizer. Aust. J. Exp. Agric. Anim.

Husb., 23 : 73-79 (Cited from Triticale Abstr., 9 : 345).

Gregory, F.G. 1937. Mineral nutrition of plants. Ann. Rev. Biochem., 6 : 557-578.

Gregory, F.G. and Crowther, F. 1928. A physiological study of varietal differences in plants. I. A study of the comparative yields of barley varieties with different manuring. Ann. Botany, 42 : 757-770.

Gregory, R.S. 1974. Triticale research programme in United Kingdom. Triticale. Ottowa, Canada, IDRC, pp. 250.

Grunes, D.L. and Krantz, B.A. 1958. Nitrogen fertilisation increases N, P and K concentration in Oats. Agron. J., 50 : 729-732.

Grunes, D.L., Viets, F.G. Jr and Shih, S.H. 1958. Proportionate uptake of soil and fertiliser P by plants as affected by N fertilisation. I. Growth Chamber Experiments. Proc. Soil Sci. Soc. Am. 22 : 43-48.

Gupta, A.P.; Virmani, S.M. and Tyagi R.C. 1972. Relative direct efficacy of some phosphatic fertilisers. Indian J. agric. Sci. 42 : 351-356.

Gupta, Y.P. 1990. Record food output. Hindustan Times, 117 : (12), 12th Jan. 1990.

Hagen, C.E. and Hopkins, H.T. 1955. Ionic species in orthophosphate absorption by barley roots. Plant Physiol. 30 : 193-199 (Cited from "Soil Plant Relationships", C.A. Black, ed., Wiley Eastern Private Ltd., New Delhi.).

Hewitt, E.J. 1963. Mineral nutrition of plants in culture media. In : "Plant Physiology - A Treatise", vol. III. F.C. Steward, ed., pp. 97-133. Academic Press, New York.

Hewitt, E.J. and Afridi, M.M.R.K. 1959. Adoptive synthesis of nitrate reductase in higher plants. Nature, 183 : 57-58.

Hulse, J.H. and Spurgeon, D. 1974. Triticale, Scientific American, 231 : 72-80.

Humphries, E.C. and Wheeler, A.W. 1963. Ann. Rev. Plant Physiol, 14 : 385-410 (Cited from Gardner et al. 1985).

Inam, A. 1978. "Mineral Nutrition of Triticale". Ph.D. Thesis, Aligarh Muslim University, Aligarh (Cited from Triticale Abstr. 8(2).

Inam, A. 1992. Triticale - A Potential Crop of Future. Indian Rev. of Life Sci., 12 : 263-278.

Inam, A.; Samiullah; Afridi, M.M.R.K.; Ahmad, A.; Ashfaq . N. and Alvi, M.S. 1982a. Observation on the effect of NPK fertiliser on germination of triticale. Comp. Physiol. Ecol., 7 : 49-50.

Inam, A.; Samiullah; Afridi, M.M.R.K.; Ahmad, A. and Sahni, M.L. 1982b. Leaf nutrient content NPK fertilisation relationship among triticale genotypes. Comp. Physiol. Ecol., 7 : 154-157.

Inam, A.; Samiullah and Afridi, M.M.R.K. 1985. Triticale in relation to NPK fertilisation. Geobios, 12 : 193-196.

Inam, A.; Samiullah and Ahmad, A. 1992. Effect of basal nitrogen and spray phosphorus on yield characteristics of triticale. Geobios, 19 : 137-139.

Irvine, G.N. and McMullan M.E. 1960. The "Remix" Baking Test. Cereal Chem., 37 : 603-608.

Ivano, A. Prokopenko, S. 1976. Physico-chemical and bread-making qualities of a amphidiploid triticale. Tritologiya i Genetika, 10 : 114-118 (Cited from Triticale Abstr. 4 : 85).

Jaworski, E.G. 1971. Nitrate reductase assay in intact plant tissues. Biochem. Biophys. Res. Commun. 43 : 1274-1279.

Jenkins, B.C. 1974. Hexaploid triticale : past, present and future, 56-61 (Cited from Triticale Abstr., 1 : 46).

Kalra, G.S. and Dhiman, S.D. 1979. Productivity and quality response of wheat and triticale to nitrogen. Indian J. agric. Res. 13 : 225-228.

Khalique, A. 1975. "Comparative Studies of the Effect of Soil and Leaf-Applied Nutrients on Some Crop Plants". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Khan, F.A. 1988. "Growth and Yield Response of Lens culinaris L. Medic and Vigna radiata L. Wilczke to Nitrogen and Phosphorus Application". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Kiss, Á. 1968. Triticale. Budapest : Mezögazdosági Kiadó, p. 180 (Cited from Field Crop, Abstr., 24 : 1545).

Kiss, Á. 1973. Table 5. In : Results of the Second and Third International Triticale yield Nurseries 1970-71, 1971-72. Information Bulletin No. 10, CIMMYT, Mexico.

Kiss, Á. 1974. Triticale - breeding experiments in Eastern Europe. IDRC Report 024e, 41-50 (Cited from Trans. Bot. Soc. Edinb., 42 : 505-512).

Kiss, Á. and Feher, B. 1968. Agrolechnics of Triticale. Bull. Agric. Exp. Inst., 2 : 69-72 (Cited from Field Crop Abstr., 22 : 861).

Kohli, M.M. 1973. Broadening adaptation in triticale. CIMMYT Research Bull. No. 24 : 70-73.

Kolev, D. and Khristov, S. 1983. Effect of increasing fertiliser rates on grain yield and quality of some triticale cultivars grown in North Eastern Bulgaria, Rasteniev dni Nauki, 20 : 55-60 (Cited from Triticale Abstr. 6 : 4717).

Kow, Y.W.; Frbes, D.L. and Gibbs, M. 1982. Chloroplast respiration. A means of supplying oxidized pyridine nucleotide for dark chloroplast metabolism. Plant Physiol., 69 : 442-447 (Cited from Noggle, G.R. and Fritz, G.J. 1986).

Koźmina, N.P.; Voronova, E.A.; Khachaturyan, E.E.; and Zagnetova, S.I. 1976. Evaluation of the baking quality of the flour in triticale. Selektsiya i Semenovodstvo No. 3; 27-28 (Cited from Triticale Abstr., 3 : 51).

Kudryavtseva, A.A. 1977. Evaluation of hexaploid spring triticales for some economically useful characters. Referativnyi Zhurnal, 12 : 145 (Cited from Triticale Abstr., 6 : 43).

Lafever, H.N. and Schmidt W.H. 1972. Triticale. Ohio Report on Res. and Deve. 57 : 3-5.

Lal, K.N. and Prasad, G. 1947. Proc. natl. Acad. Sci (India), 17 : 83.

Langer, R.H.M. 1966. Mineral nutrition of grasses and cereals in "The Growth of Cereals and Grasses". Milthorpe, F.L. and Ivins, J.D. eds., p. 213 Butterworths, London.

Langer, R.H.M. 1972. How Grasses Grow. London Edward Arnold (Cited from Gardner et al. 1985).

Larter, E.N.; Gustafson, J.P. and Zillinsky, F.J. 1978. Welsh triticale, Can. J. Plant Sci., 58 : 879-880.

Lewis, D. 1936. A note on the absorption ofsolutes by leaves. J. Pomal., 14 : 391.

Lindner,R.C. 1944. Rapid analytical methods for some of the more common inorganic constituents of plant tissues. Plant Physiol., 19 : 76-89.

Longstreth, D.J. and Nobel, P.S. 1980. Nutrient influences on leaf photosynthesis. Plant Physiol. 65 : 541-543.

Lorenz, K.; Welsh, J.; Normann, R. and Maga, J. 1972. Comparative mixing and baking properties of wheat and triticale flours. Cereal Chem. 49 : 187-193.

Lowry, O.H.; Rosebrough, N.J.; Farr, A.L. and Randall, R.J. 1951. Protein measurement with folin phenol reagent. J. Biol. Chem., 193 : 265-275.

Lundegårdh, H. 1951. "Leaf analysis" (Translated by R.L. Mitchell). Hilger and Watts Ltd., London.

Marschner, H. 1986. "Mineral Nutrition of Higher Plants". Academic Press. London.

Mazurek J. and Mazurek J. 1974. Investigations on agronomic practices for triticale. 1. Effect of sowing rate and date and of fertilization on yield of triticale and of spring wheat. Pamietnik Pulawski, No. 60 : 67-76 (Cited from Triticale Abstr., 3:136).

McNeal, F.H.; Berg, M.A.; Brown, P.L. and McGuire, C.F. 1971. Productivity and quality response of five spring wheat genotypes Triticum aestivum L. to nitrogen fertilisers Agron. J., 63 : 608.

McNeal, F.H.; Watson, C.A. and Kiltams, H.A. 1963. Effect of dates and rates of nitrogen fertilisation on the quality and field performance of five hard red spring wheat varieties. Agron. J., 55 : 470.

Mengel, K. and Kirkby, E.A. 1982. "Principles of Plant Nutrition". III ed., International Potash Institute Bern., Switzerland.

Milthorpe, F.L. and Moorby, J. 1979. "An Introduction to Crop Physiology". Cambridge University Press, London.

Misra, P.N. 1977. Note on response of triticale varieties to nitrogen doses grown in alkaline soils. Pant nagar J. Res. 2 : 95-96.

Mishra, B.; Sharma, R.D. and Mishra, H.P. 1980. Use of Mussoorie rock phosphate mixed with superphosphate or low-grade pyrites as alternative phosphorus source for wheat on neutral soils. Indian J.Agric. Sci., 59 : 346-351.

Mitchell, J. 1957. A review of tracer studies in Saskatchewan on the utilisation of phosphate by grain crops. J. Soil Sci., 8 : 73-85.

Modi, M.S. and Lal, P. 1981. Grain yield and nutrient uptake of triticales in relation to wheat at varying levels of nitrogen under unirrigated condition. Indian J. Agron., 26 : 307-312.

Mohammad, F. 1989. Effect of Soil and Leaf applied phosphorus on the yield and quality of Linseed. Indian J. Plant Physiol, 32 : 25-30.

Mohammad, F.; Samiullah and Afridi, M.M.R.K. 1986a. Effect of phosphorus and sulphur spray on mustard yield. Geobios, 13 : 8-12.

Mohammad, F.; Samiullah and Afridi, M.M.R.K. 1986b. Comparative response of ten varieties of mustard (*Brassica juncea* L. Czern & Coss) to combined spray of N, P and S. Ibid, 13 : 168-172.

Mohapatra, P.K.; Patnaik, D.P. and Mishra, B.C. 1983. Phosphorus nutrition and spikelet production the main shoot apex in wheat, *Triticum aestivum* Var. Sonalika. Indian J. Plant Physiol., 26 : 314-318.

Moinuddin 1987. "Mineral Nutrition of Triticale in relation to its parents". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Moinuddin, 1989. Nutrient requirement of triticale III. Leaf NPK index in relation to grain yield and quality. J. Indian bot. Soc. 68 : 309-312.

Moinuddin, Samiullah; Afridi, M.M.R.K. and Inam, A. 1985. Nutrient requirement of triticale. I. Effect of nitrogen and phosphorus on growth characteristics of four new varieties. National Seminar on Plant Physiology. Abstr. No. 15, p. 12, Manipur University, Canchipur.

Moinuddin; Samiullah; Afridi, M.M.R.K. and Inam, A. 1990. Comparative studies on physio-agronomic performance of Mexican triticales with wheat and rye. Geobios, 17 : 73-77.

Moorby, J. and Besford, R.T. 1983. Mineral nutrition and growth. In : "Encyclopedia of Plant Physiology", 15B : 481-527, A. Lauchli and R.L. Bieleski, eds. Springer-Verlag, New York.

Moss, D.N. 1988. Photosynthesis, Respiration and Photorespiration in Higher Plants. In : "Physiological Basis of Crop Growth and Development", pp. 131-152 M.B. Tesar ed . American Society of Agronomy, Crop Science, Society of America, Madison, Wisconsin.

Mukherji, B.K. and Agarwal, R.R. 1944. Preliminary study of the influence of variety, manures and irrigation on the composition and quality of barley. Indian J. Agric. Sci., 14 : 109-116.

Müntzing, A. 1974. Historical review of the development of triticale. IDRC Report 024e, 13-30, Ottawa, Canada (Cited from Trans. Bot. Soc. Edinb., 42 : 505-512).

Murti, G.S.R. 1972. "Studies on nitrate reductase activity as influenced by photoperiods, nitrogen and growth regulators in wheat (*Triticum aestivum* L.). Ph.D. Thesis, I.A.R.I., New Delhi.

Naik, M.S.; Abrol, Y.P.; Nair, T.V.R. and Rama Rao, C.S. 1982. Nitrate assimilation its regulation and relationship to reduced nitrogen in higher plants. Phytechemistry 21 : 495-504.

Nair, T.V.R. and Abrol, Y.P. 1982. Nitrate reductase activity in flag leaf blade and its relationship to protein content and grain yield in wheat (*Triticum aestivum* L.) Indian J. Plant Physiol., 25 : 111-122.

Naqvi, A. 1976."Studies on the Effect of Foliar Nutrition on the Growth and Yield of Barley and Mustard". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Naqvi, A.; Afridi, M.M.R.K. and Samiullah 1977. Effect of phosphorus and sulphur on the growth and yield of Laha-101. Geobios, 4 : 253-254.

Nass, H.G.; Kunelius, H.T. and Suzuki, M. 1975. Effect of nitrogen application on barley, oats and triticale grown as forage. Canadian J. Plant Sci., 55 : 49-53.

Nasr, H. and Guivagossian, V. 1972. Table 20, In : Results of the First International Triticale yield Nursery, 1969-70. Information Bulletin No. 1, CIMMYT, Mexico.

Nataraju, S.P.; Udaykumar, M.; Gurumurthy, B.R. and Umesha, K. 1990. Genotypic variations in nitrate reductase activity, nitrate flux and reducing sugars in finger millet (Elucine coracana Gaertn). Indian J. Plant Physiol. 33 : 145-149.

Natr, L. 1972. Influence of mineral nutrition of photosynthesis of higher plants. Photosynthetica 6 : 541-543. (Cited from Mohapatra et al. 1983).

Nicholls, P.B. 1974. Inter-relationship between meristematic regions of developing inflorescence of four cereal species. Ann. Bot., 38 : 827-837.

Noggle, G.R. and Fritz, G.J. 1986. "Introductory Plant Physiology", II ed., Printice Hall of India, Private Ltd., New Delhi.

Noor, A. 1986. "Mineral Nutrition of Radish and Turnip". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Orphanos, P.I. and Krentos, V.D. 1980. Concentration of N, P and K in leaves, straw and grain of wheat and barley as influenced by N and P fertilisers under semi-arid conditions. J. Agric. Sci (Camb), 94 : 551-556.

Osman, A.M.; Goodman, P.J. and Cooper, J.P. 1977. The effect of nitrogen, phosphorus and potassium on rates of growth and photosynthesis in wheat. Photosynthetica, 11 : 66-75 (Cited from Mohaptra et al., 1983).

Pancholi, D.K. and Bishnoi, N.R. 1980. Effect of different N fertilisation rates on triticale in comparison to wheat and rye. Agronomy Abstr., 104 (Cited from Triticale Abstr., 7 : 167).

Panse, V.G. and Sukhatme, P.V. 1985. "Statistical Methods for Agricultural Workers". IV ed., Indian Council of Agricultural Research, New Delhi.

Parvaiz, M.A. 1979. "Mineral Nutrition of Mustard". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Parvaiz, M.A.; Afridi, M.M.R.K. and Samiullah 1982. Critical growth stage for optimal response of mustard to foliar application of nitrogen, phosphorus and sulphur. Indian J. Plant Nutrition, 1 : 43-48.

Patnaik, N. 1987. Soil Fertility and Fertiliser use. In : "Hand Book of Agriculture". pp. 212- By the Indian Council of Agricultural Research (ICAR), New Delhi.

Pino, N.I. and Rodriguez, S.J. 1980. Nitrogen economy in genotypes of wheat (Triticum aestivum) and triticale (Triticosecale spp.) I. Effect of nitrogen on the production of dry matter, grain and protein. Anales de Edafologia Y Agrobiologia, 39 : 1369-1377. (Cited from Triticale Abstr., 8 : 177).

Pleshkov, B.P.; Shulyndin, A.F. and Emel'yanova I.P. 1983. Content and composition of grain proteins of triticale under different levels of nitrogen nutrition. Izvestiya Sel'skokhozyuistvennoi Akademii No. 2, 74-79.

Ponce, A.O.; Zarate DEL.G.; Tah, I.J.F. 1981. Effect of three methods of cultivation with different N,P,K fertiliser rates in two triticale sp. cultivars in Winter Chapingo No. 31/32, 67-73 (Cited from Triticale Abstr. 9 : 163).

Prasad, R. and Singh, S. 1983. Relative efficiency of triticale and spring wheat in utilizing phosphate from different fertilizers. Cereal Research Communication, 11 : 153-154 (Cited from Wheat, Barley and Triticale Abstr., 1 : 2034).

Primost, E. 1956. The effect of high nitrogen application on the quality of various winter wheat varieties. Z. Pflernahr Dung., 74 : 42 (Cited from Field Crop Abstr., 10 : 413).

Prohaszka, K.; Czerni, I. and Feher, B. 1971. Effect of nitrogen on yield and mineral matter content in triticale. Acta Agronomica Academiae Scientiarum Hungaricae 20 : 101-107.

Qaseem, S.M. 1975."Effect of nitrogenous and phosphatic spray on the yield and grain quality of barley and wheat". Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Qaseem, S.M.; Afridi, M.M.R.K. and Samiullah 1978. Effect of leaf applied phosphorus on the yield characteristics of ten barley varieties. Indian J. Agric. Sci., 48 : 215-217.

Rahman, M.S. and Wilson, J.H. 1977. Effect of phosphorus applied as superphosphate on rate of development and spikelet number per ear in different cultivars of wheat. Aust. J. Agric. Res., 28 : 183-186.

Rao, K.P.; Rains, D.W.; Qualset, C.O. and Huffaker, P.C. 1977. Nitrogen nutrition and grain protein in spring wheat genotypes differing in nitrate reductase activity. Crop Sci., 17 : 283-286.

Reddy, G.G. and Lal, P. 1976. Physiological analysis of yield variation in triticale and wheat varieties under unirrigated conditions. Indian J. Plant Physiol. 19 : 154-163

Riman, L. Ránkoezi, L. 1977. Study of the mill and baking quality of selected collection of triticale. Vedecki Práce Výskumne'ho Ústaavu Rastlinnej Výreby v Pieštanoch 14 : 183-191 (Cited from Triticale Abstr. 6(4).

Rooney, I.W.; Gastafson, C.B.; Perez, N. and Porter, K.B. 1969. Agronomic performance and quality characteristics of triticale grows in the Taxas High Plains, Progress report. Taxas Agri. Exp. Sta. (Cited from Food Technology 66-74, 1972).

Roy, R.H. and Wright, B.C. 1974. Sorghum growth and nutrient uptake in relation to soil fertility. N, P and K uptake pattern in various plant parts. Agron. J., 66 : 5-10.

Russell, E.J. 1950. "Soil Conditions and Plant growth", VIII ed., Longmans Green and Co., New York.

Sacchidanand, B.; Sawarkar, N.J.; Churayya, R.S.; Shinde, D.A. and Sinha, S.B. 1980. Response of soyabean to sulphur and phosphorus. J. Indian Soc. Soil, 28 : 101-104 (Cited from Upadhyay et al. 1988).

Safaya, N.M. 1971. "Studies on Nitrogen,Phosphorus and Potassium Nutrition in Three Varieties of Barley (Hordeum vulgare L.). Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Saini, A.D. and Nanda, R. 1974. Observations on growth and yield in wheat. Indian Journal of Genetics and Plant Breeding 34A, 1001-1011.

Salisbury, F.B. and Ross, C.W. 1991. "Plant Physiology". IV ed. pp. 116-135. Wadsworth Publishing Company, Belmont, California.

Samiullah 1971. "Effect of Phosphorus on the Nutrition, Growth and Malting Quality of Barley (Hordeum vulgare L.)" Ph.D. Thesis, Aligarh Muslim University, Aligarh.

Samiullah and Afridi, M.M.R.K. 1975. Comparison of the effect of soil and leaf applied phosphorus on the malting quality of the grain of barley (Hordeum vulgare L.). Indian J. Plant Physiol., 18 : 121-126.

Samiullah; Inam, A.; Afridi, M.M.R.K.; Ahmad, A. and Parvaiz, M.A. 1987. Effect of different combinations of basal NPK on growth characteristics of Triticale. Comp. Physiol. Ecol., 12 : 97-99.

Samiullah, Mohammad, F. and Afridi, M.M.R.K. 1985. On optimising mustard yield by spray of nitrogen, phosphorus and sulphur. In : "Recent Trends in Botanical Research", pp. 137-143, Gohil, R.N. (ed.).

Samiullah; Moinuddin; Afridi, M.M.R.K. and Inam, A. 1991. Determination of sowing date for triticale. I. Effect of four sowing dates on leaf N P K content, grain yield and quality of four new triticales. In: New Trends in Plant Physiology : 211-216. K.K. Dhir, I.S. Dua and K.S. Clark (Eds.).

Saurer, W. and Dormann, A. 1979. Some studies on the baking qualities of triticale. Schweizerische Landwirlschaft, 27 : 69-75.

Sayed, H.I. and Al-Saad, F.A. 1979. Foliar application of nutrients and its effect on grain yield and quality of wheat and triticale. Proceedings of the Saudi Biological Society No. 3 : 47-56 (Cited from Triticale Abstr. 7 : 109).

Schlehuber, A.M. and Tucker, B.B. 1959. Factors affecting the protein content of wheat. Cereal Sci. Today, 4 : 240.

Sethi, G.S.; Asawa, B.M.; Singh, H.B. and Asawa, R.K. 1979. Factor analysis of grain yield in triticale. Indian J. Agric. Sci., 49 : 504-506.

Sethi, G.S. and Singh, H.B. 1972. Interrelationship of quantitative traits with grain yield in Triticale. Indian J. Agric. Sci., 42 : 281-285.

Sharma, H.C. and Singh, M.R. 1973. Effect of soil moisture regimes, phosphorus and nitrogen on N and P uptake by barley (Hordeum vulgare L.) Indian J. Agri.Sci., 43: 58.

Sharma, Y.K.; Deodhar, A.D. and Mishra, A. 1977. Evaluation of physico-chemical characteristics determining the chapati making qualities of triticale. Indian Journal of Nutrition and Dietetics 14 : 140-145.

Siddiqui, N. 1974. "Some aspects of the mineral nutrition of selected cereals". M.Phil. dissertation, Aligarh Muslim University, Aligarh.

Silberstein, O. and Wittwer, S.H. 1951. Foliar application of phosphatic nutrients to vegetable crops. Proc. American Soc, Hort. Sci., 58 : 179-198.

Singh, S.D. and Gupta, M.L. 1969. Relative efficiency of nitrogenous fertilisers in the presence and absence of phosphorus on wheat. I. Yield and grain protein content. Indian J. Agron. 14 : 262-270.

Singh, V.P. and Singh, M. 1985. Nitrate reductase activity and its relationship with grain protein and grain yield. Indian J. Plant Physiol., 28 : 235-242.

Slootmaker, L.A.J. 1974. Tolerance to high soil acidity in wheat related species rye and triticale. Euphytica 23 : 505-513.

Smith, T.E. 1967. "Triticale grain of the future". Crops Soils, 19 : 15.

Stankova, P.G. and Matsov, B.N. 1982. The drought resistance of certain local and introduced cultivars of wheat and triticale. Fiziol Rast., 8 : 84-92. (Cited from Biol. Abstr., 76 : 79).

Stepanov, N.S. 1965. Spraying plants with urea improves seed quality. Selek Semenorod No. 1 : 37 (Cited from Field Crop Abstr., 18 : 1695).

Stepochkin, P.I. and Vladimirov, N.S. 1985. Frost resistance of siberian (U.S.S.R.) triticale forms at various ploidy levels. S-KH Biol., 0(4): 56-58 (Cited from Biol. Abstr. 80 : 91795).

Tabl, M.M. and Kiss, Á. 1986. Influence of nitrogen fertilizer and plant densities on yield and yield components of hexaploid triticale and wheat. Acta Agronomica Hungarica 35 : 91-96 (Cited from Wheat, barley and triticale Abstr. 4 : 683; 5918).

Tahir, M. 1978. Achievements in research and production in winter cereals in Pakistan. In : "Technology for Increasing Food Production". Holmes, J.C. (ed.) pp. 453-462. Rome, Italy (Cited from Triticale Abstr., 6 : 117).

Tamhane, R.V.; Motiramani, D.P.; Bali, Y.P. and Donahue, R.L. 1970. "Soils : Their Chemistry and Fertility in Tropical Asia". Printice Hall of India Pvt. Ltd., New Delhi.

Terry, N. and Ulrich, A. 1973a. Effects of phosphorus deficiency on the photosynthesis and respiration of leaves in sugar beet. Plant Physiol., 51 : 43-47.

Terry, N. and Ulrich A. 1973b. Effects of potassium deficiency on the photosynthesis and Respiration of Leaves of Sugar Beet. Plant Physiol. 51 : 783-786.

Terry, N. and Ulrich, A. 1973c. Effects of Potassium Deficiency of Sugar Beet under conditions of Low Sodium Supply. Plant Physiol, 51 : 1099-1101.

Thorne, G.N. 1958. Factors affecting uptake of radioactive phosphorus by leaves and its translocation to other parts of the plant. Ann. Bot. 22 : 381-398.

Thorne, G.N. 1963. Varietal differences in photosynthesis of ears and leaves of barley. Ann. Bot. (A.S.), 27 : 155.

Touraine, B. and Meimoun, A. 1985. Comparison of salt tolerance in triticale and barley. Agronomic (Paris), 5 : 391-396 (Cited from Biol. Abstr., 80 : 82629).

Tsen, C.C.; Hoover, W.J. and Farrel, E.P. 1971. Baking quality of triticale flours. Abstract, AAAC 56th Ann. Meet., Dallas (Cited from Food Technology Nov.1972, pp. 66-74).

Tsen, C.C.; Hoover, W.J. and Farrell, E.P. 1973. Baking quality of triticale flours. Cereal Chem., 50 : 16-76.

Turbin, N.V.; Khilyupkin, V.M. and Zhebrak, E.A. 1980. Spring triticale a cover crop for herbarge species. Kormoproizvodstvo No. 8, 24-25 (Cited from Triticale Abstr., 8 : 114).

Unrau, A.M. and Jenkins, B.C. 1964. Investigations on synthetic cereal species. Milling, Baking and some compositional characteristics of some "Triticale" and Parental Species. Cereal Chem., 41 : 365-374.

Upadhyay, A.P.; Deshmukh, M.R.; Rajput, R.P. and Deshmukh, S.C. 1988. Effect of sources, levels and methods of phosphorus application of plant productivity and yield of soyabean. Indian J. Agron., 33 : 14-18.

Upadhyaya, Y.M. 1973. Table 6. In : Results of the second and Third International Triticale Yield Nurseries, 1970-71, 1971-72. Information Bulletin No. 10, CIMMYT, Mexico.

Vaulina, G.I. 1987. Effect of mineral nutrition and weather conditions on formation of grain yield and quality of triticale. Agrokhimiya No. 7 : 37-43 (Cited from Wheat, barley and triticale Abstr., 5 : 676).

Villegas, E. 1973. Improving nutritional quality of triticale. In : CIMMYT Res. Bull. No. 24 : 55-63. Zillinsky F.J. (ed.) CIMMYT, Mexico.

Volk, R. and McAuliffe, C. 1954. Factors affecting the foliar absorption of N^{15} labelled urea by tobacco. Amer. Soc. Soil Sci. Proc., 18 : 308.

Vose, P.B. 1963. Varietal differences in plant nutrition. Herb. Abstr., 33 : 1-13.

Wahhab, A. and Hussain, I. 1957. Effect of nitrogen on growth, quality and yield of irrigated wheat in West Pakistan. Agron. J., 49 : 116-119.

Wallace, T. 1961. "The Diagnosis of Mineral Deficiencies in Plants". (III ed). Her Majestys Stationery Office, London.

Webster, G.C. 1959. Nitrogen Metabolism in Plant. Row Peterson and Company, Evanston, Ill.

Yatazawa, M. and Higashino, S. 1953. Mechanism of foliar absorption of phosphate. II. Forms of transferring phosphate after the foliar absorption. J. Sci. Soil Manure, Japan, 24 : 193-196 (Cited from Chem. Abstr., 48 : 4057).

Yatazawa, M. and Tai, K. 1953. Mechanism of foliar absorption of phosphate. I. The effect of accompanied sugars on absorption of phosphate. J. Sci. Soil Manure, Japan, 24 : 93-95 (Cited from Field Crop Abstr., 8 : 152).

Yih, R.Y. and Clark, H.E. 1965. Carbohydrate and protein content of boron-deficient tomato root tips in relation to anatomy and growth. Plant Physiol., 40 : 312-315.

Yoshida, S. 1972. Physiological aspects of grain yield. Ann. Rev. Plant Physiol., 23 : 437-464.

Zaťko, J. 1978. Effect of some agronomic practices on the grain yield of triticale No. 64. Pol'nohospodárstv, 24 : 125-132 (Cited from Triticale Abstr., 6 : 61).

Zenyuk, I.A. 1970. Role of N fertilisers in improving grain quality of winter wheat. SB. Nauchn. Trud. Grodnen sel-Khoz. Inst. No. 7 : 18 (Cited from Field Crop Abstr., 24 : 4468).

Ziesel, J.F.; Rivenbark, W.L. and Hageman, R.H. 1963. Crop Sci., 3 : 27-32 (Cited from Gardner et al., 1985).

Zillinsky, F.J. and Borlaug N.E. 1971a. Progress in developing triticale as an economic crop. Research Bull. No. 17, pp. 27, CIMMYT, Mexico.

Zillinsky, F.J. and Borlaug, N.E. 1971b. Triticale research in Mexico. Agric. Sci., Rev. 9 : 28-35.

Zillinsky, F.J. and Lopez, B.A. 1973. Breeding for improved agronomic characteristics. In : "Triticale Breeding and Research at CIMMYT - A Progress Report", Zillinsky, F.J. (ed.). Research Bull. No. 24 : 12-30, CIMMYT, Mexico.

Zillinsky, F.; Skovmand, B. and Amaya, A. 1980. Triticale : adaptation, production and uses. Span, 23 : 83-84, CIMMYT, Londres, Mexico.